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Assessing Self-Regulation of Learning Dimensions in a Stand-alone MOOC Platform

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Daniel F.O. Onah
The University of Warwick, Coventry, United Kingdom
d.f.o.onah@warwick.ac.uk

Jane E. Sinclair
The University of Warwick, Coventry, United Kingdom
j.e.sinclair@warwick.ac.uk

Abstract—A capacity for self-regulated learning (SRL) has long been recognised as an important factor in successful studies. Although educational researchers have started to investigate the concept of SRL in the context of online education, very little is yet known about SRL in relation to massive open online courses (MOOCs) or of appropriate strategies to foster SRL skills in MOOC learners. Self-regulation is particularly important in a MOOC-based study, which demands effective independent learning, and where widely acknowledged high dropout rates are observed. This study reports an investigation and assessment of the concept of SRL using a novel MOOC platform (eLDa) by providing study options (either via a self-directed learning or instructor-led learning) using a novel learning tool. In view of this, the research presents general description of self-regulated learning and explored the various existing dimensions used to expose the learners SRL skills. Drawing comparison of the online tool, the results and findings of the data were analysed. The study discusses how the various dimensions contributed to the knowledge representation of the self-regulated learning abilities shown by the learners. We present how these SRL dimensions captured using the measuring instrument contributes to our growing understanding of the distinctive features of the individual learner's self-regulated learning. MOOCs success required a high performance of self-regulated learning abilities which at the moment very little has shown these degree of supporting SRL skills. This paper presents preliminary evaluation of a novel e-learning tool known, as 'eLDa' developed to implement this investigation of self-regulation of learning. The research applied a modified online self-regulated learning questionnaire (OSLQ) as the instrument to measure the SRL skills. The modified questionnaire known as MOOC OSLQ (MOSLQ) was developed with a 19-item scale questions that exposes the six SRL dimensions used in this study.

Keywords—self-regulated learning, self-directed learning, instructor-led learning, learning patterns, learning modes, MOOCs

1 Introduction

Online education systems such as massive open online courses (MOOCs) with an open environment have grown around the globe and have been broadcasted widely. Nonetheless, many participants who registered for these courses are not completing and thus it led to the high dropout rates publicised in papers and the media. The low accomplishment rates of less than 15% completion rates have been recognised as one of the main difficulties within MOOCs [1]. MOOC participants represent large online learning community with distinct motivational interest. Research shows that one of the causes of the low completion rate in MOOC could be due to the lack of motivation and procrastination within the learners to self-regulate and engage consistently with the course [2]. It has been known that learners who exhibit the ability to self-regulate their learning perform better academically as compared to learners with non or minimal self-regulated learning skills [3, 4]. This research described the self-regulated learning ability identified among different learners' modes of study. The two main modes are: self-directed and Instructor-led modes. The study focuses on examining and investigating whether there exists better performance of self-regulated learning strategies among the learners from related study mode. In order to investigate the self-regulated learning dimensions, a novel 'eLDa' tool was developed to deliver a course in 'Python programming, computing concepts and how to teach computing in schools'. This study introduces this novel approach of learning which aims to allow learners to actively study in their own chosen path, and also providing the framework of an instructional direction to support participants in order to set-goals and to gain access to materials suitable for their own needs.

We predict equal and associated higher or lower SRL skills among the participants, because of the fact that most of our learners are highly educated, professionals, graduates and undergraduates in their different and similar levels. However, that is not the case with this study, our investigation reveals some aspects of low self-regulators observed in some dimensions including help-seeking and task strategies. This demonstrates that even learners of higher educational background may not be able to fulfill all the requirements necessary to be (or of been) called a high self-regulator and may need to improve in some of the strategies (or dimensions) lacking. This research is of imperative and impeccable value to the establishment and encouragement of self-regulated learning in MOOCs and also on the evaluation of the learners' cognitive ability in developing these skills.

The paper is organised as follows, firstly a review of background of self-regulated learning. Secondly, we present a discussion of the various research methods applied in the research. Thirdly, we present preliminary results from our findings. Finally, we then present the research discussion and contribution, the conclusion and further direction.

2 Related review

2.1 Background of self-regulated learning

At one point or the other we have all observed self-regulated learning during our studies and careers. According to Barnard-Brak et al. [4], self-regulated learning refers to volitional behaviours on individual learners part to succeed in their learning. Those behaviours include but not limited to the following: setting up study goals (goal setting), strategising effective way of solving the task given (task strategies), planning an effective managing study time (time management), deciding on location of study to acquire optimum benefit with low distractions (environment structuring), requesting for assistance from peers and tutors in providing help in area of concern (help seeking) and lastly self-reflection on personal studies to evaluate the goals achieved (self-evaluation). SRL allows learners to approach educational tasks with confidence, diligence and in a resourceful manner [5, 6]. Zimmerman explains that self-regulated (SR) learners are knowledgeable and aware of when they are confident on a particular fact and when they posses the skills to resolve the task successfully and also they are aware of when they cannot [7]. On the other hand, unlike passive learners, SR students or learners are known to be proactive seeking out the necessary information needed, and then further develop personal steps to master it. These SRL learners always find a way out of any difficult situation (or obstacle) during their studies and learning processes in order to succeed. In a similar way, SR learners view learning acquisition as a systematic and controllable learning process. The learners accept responsibility for their outcomes and attainment [8, 9, 10]. SR learners are known to be self-starters with extraordinary confident, they are highly persistent during their studies. They choose environments that will help them optimize their learning approach [9, 11, 12]. SR learners seek sufficient information and advice on environment they are most likely to concentrate and learn effectively. According to some studies, SR learners self-direct their knowledge acquisition and self-reinforce during performance enactments [13,14].

When defining SRL, it is imperative to distinguish it from self-regulation processes such as self-efficacy and dimensions (or strategies) which were created to optimize the processes, such as intermediate goal setting, task strategies, time management, environment structuring, help-seeking and self-evaluation as adapted for this study [2, 3]. In another definition, SRL is defined as a self-oriented feedback loop [15, 16]. This loop involves a cyclic process which allows the students to monitor the effectiveness of their learning strategies and react to the feedback in a variety of ways, such as changing their self-perception in order to alter their learning behaviour strategies [6]. Although this involves the learners showing proactive effort and be vigilant in allocating enough time in preparation in order to initiate control and self-regulate their learning [17]. McCombs view was different, as they view learners as being motivated by an excellent 'sense of self-esteem or self-actualisation' [18]. Other theorist such as self-efficacy, achievement success and cognitive equilibrium favours motives of self-regulated learning [7, 19, 20]. Self regulated learners self-initiate personal activities in order to promote self-observation, self-evaluation, reflexivity in learning,

and improvement which could be seen in practice sessions, specialty training and competitive activities [9]. Bandura described the ability of the learners to set higher learning goals for themselves after they have achieved initial goals, shows that they possess the quality of self-motivation [21], in a similar theory, Csikszentmihalyi adduced that an enjoyable experience encourages people to continue to engage in an activity 'even at a greater expense of doing it' [22].

SRL involves proactive efforts to seek benefits from the learning process. In this case, the learners are not only self-directed in a metacognitive manner, but also are self-motivated by using integrated skills of self-regulations [23]. In summary, self-regulated learning has been categorized into three main features: (a) the learners use of self-regulated learning strategies or dimensions, (b) the learners responsiveness to self-oriented feedback on learning effectiveness, and (c) the learners independent motivational strategies which were used to achieve desired academic outcomes by incorporating responses of learning effectiveness and SRL skills [10].

3 Methodology

3.1 Overarching research methodology and processes

This study uses design science research methodology as the overarching research methods [24]. This is a paradigm centred on the development and evaluation of an artefact to address a precise problem domain. The data processes used a combination of mixed methods of qualitative and quantitative methods. The data collection process in the study was done using questionnaires created with an adopted instrument [2, 3]. The data was further analysed using statistical analysis after the coding and categorisation of the 19-item questions into six SRL strategies (or dimensions). The conceptual framework and the processes of the research methods are illustrated in Fig. 1.

3.2 The eLDa tool

Research has shown that learners with good knowledge on how to self-regulate their studies perform better than those with less ability to do so [9, 25, 26]. It has been observed that the use of self-regulated learning ability is distinctive to the learner. Although many SRL abilities such as goal setting and task strategies are constructed by the learners to suit their needs. The learning mode and direction chosen by the learners are to help them obtain optimum benefit from the online course. A novel platform, known as 'eLDa', was created to explore the approach and analyse the effects of novel features in order to encourage motivation, support and to foster self-regulation of learning. eLDa is implemented in Wordpress content management system (CMS) with plugins to support the novel features which allows the learners to chose their route to follow in the course in order to attain their own learning objectives or follow the directed path led by the instructor in order for the learners to achieve the course goals. The choice of Wordpress as CMS is imperative as it allows us to build a learning platform to support learners' chosen routes and to meet our

research objectives. This platform supports two basic modes of learning: self-directed and instructor-led in which a recommended prerequisite order of lessons helps to cover the full course curriculum [27]. Fig. 2 presents the interface of the Computing concepts and Python programming course in this study.

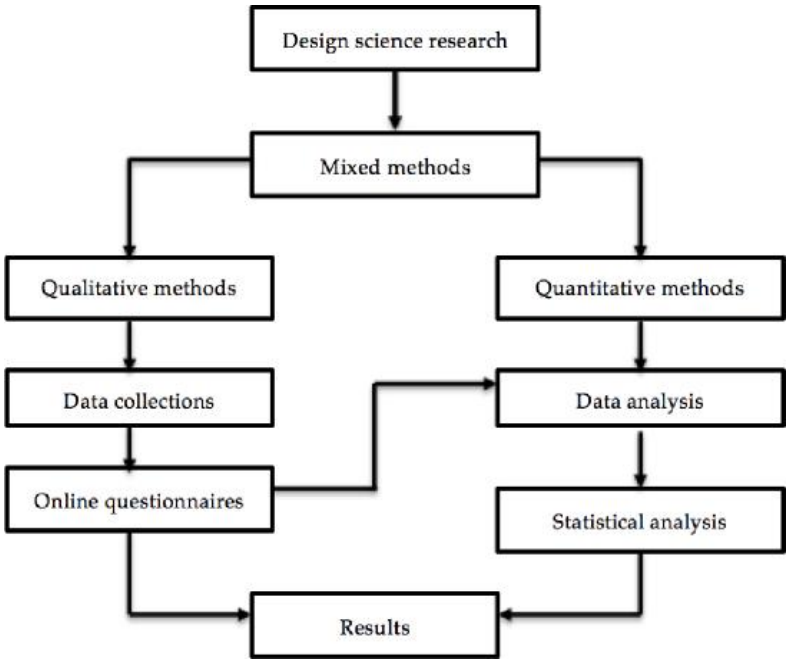

Fig. 1. Conceptual framework of the research methodology

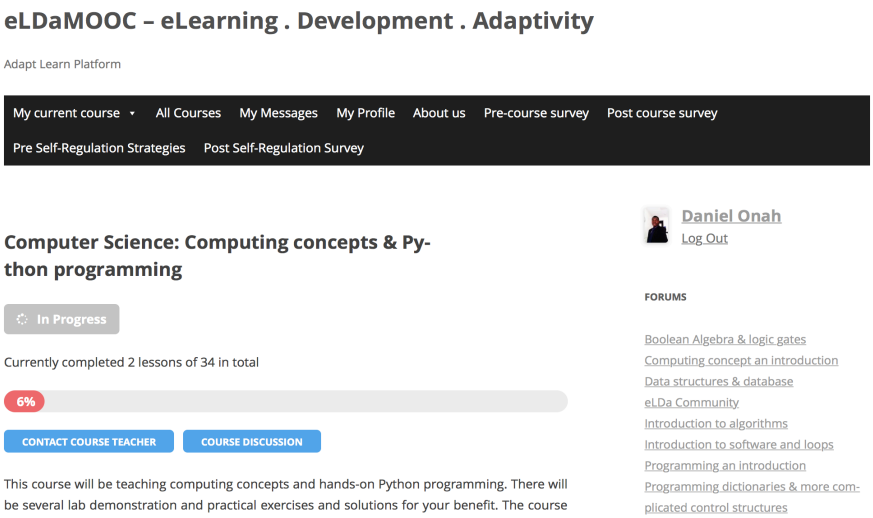

Fig. 2. Visualisation of the course platform

Participants: This study consists of a total of 107 registered participants at the beginning of the online course. Of the enrolled learners in this course, 45% (n=48) have indicated interest by engaging at least once during and after registration. However, only 27 active participants engaged with the course pre-entry survey. Out of this active participants, 59% identified themselves as male (n=16) while 41% identified as female (n =11).

For the self-regulated learning survey questions constructed using the MOSLQ instrument, only a small sample size of 11 learners out of the active 27 participants completed the survey questions used in these research findings.

Data collection processes: The data collection process was carried out using an adopted instrument known as MOOC online self-regulated learning questionnaire (MOSLQ), which was used for measuring self-regulated learning dimensions [2, 3]. A 19-item scale with 5-point Likert-type response format which constituted values ranging from 5-strongly agree to 1-strongly disagree, was applied to collect learners' responses in order for the study to be able to evaluate and answer the research questions. The MOSLQ was conducted using existing dimensions such as: goal settings (GS), task strategies (TS), time management (TM), environment structuring (ES), help seeking (HS), and self-evaluation (SE). Table 1 shows the 19-item MOSLQ instrument questions used for measuring this study.

Table 1. MOSLQ survey question

GSQ1	I know what I am going to achieve in this course
GSQ2	I have set aside time to study the course
GSQ3	I have high standards for my work on this course
GSQ4	I have set targets for all I want to achieve in this course
GSQ5	I do not see my engagement in the course as less important solely because it is an online course
GSQ6	I have written down the goals I plan to achieve by the end of this course
TSQ1	I work strategically to prioritise tasks to help me achieve my learning goals
TSQ2	I prepare for my online study by reading the suggested background learning materials beforehand
TSQ3	I set out my study agenda before engaging with the online resources
TSQ4	I am prepared to tackle any challenging aspects of the work in this course
TMQ1	I have planned ahead in order to devote the necessary time to my online studies
TMQ2	I find a good time to study when I won't be distracted
ESQ1	I choose my study location in order to avoid distractions
ESQ2	I find a comfortable place to study
ESQ3	I choose an appropriate place to work in order to study effectively
HSQ1	I plan to use the interactive communication channels provided to gain support from peers and tutors
HSQ2	I plan to participate in the course discussion forums in order to get the most out of the course
SEQ1	While engaging in this course, I will reflect on my study in each module
SEQ2	I will be proactive in engaging and reviewing progress in the learning path I select

Procedure: The MOSLQ was administered online to a population sample of 45% (n= 48) participants who have engaged with the course at least once after registration. Within these participants about 56% (n=27) were active in the course and have responded to the entry survey questions. In this study, 23% (n =11) responded to the MOSLQ for which most of the SRL dimensions results in this study were based on. However, this study when applied (to a large) in a large-scale population sample could provide significant results. After the data were collected, some of the items were coded and adapted for the research benefits. The questions in the measuring instrument were modified to suit the research objectives. The participants were assured their responses will be anonymous and in confidence. The data were imported from eLDa platform into Microsoft Excel application and then imported to SPSS (v.22.0). The Excel data were converted to comma separated values (csv) file and imported to R-Studio were further analyses was performed in order to compare the results with the SPSS analysis.

Data analysis: Analysis was performed using Statistical analysis. Descriptive evaluation of the data was done using the Statistical Package for the Social Sciences (SPSS) tool. The tool was used to evaluate the learners' responses in order to investigate individual self-regulated learning strategies and also identify the level of self-regulated learning amongst the participants. This analysis helped to reveal areas of SRL dimensions that need improving. Analyses were performed with the average score of the SRL dimensions.

4 Results

The results indicate better high self-regulated learning skills among learners that chose the path of a self-directed learning as compared to those that followed instructor-led mode of study. Following the responses from the 19-item statements that made the MOOC online self-regulated learning questionnaire (MOSLQ), we present learners associated and different pattern of self-regulated learning skills (as seen in Fig. 3). The discussion and contribution session demonstrates the results interpretation. The individual SRL skills were addressed and levels of each learners SRL skills were identified.

4.1 Visualisation of learning preferences

Fig. 4 shows profiles of learners' preferred mode of learning including: interactive learning, collaborative learning, instructor-led learning and self-directed learning respectively. The learning profiles were created by using the frequency of respondents' preferences from the survey questions. The question, which in-formed the knowledge of these preferences, is thus: 'what kind of online course delivery do you prefer?'. The learners can choose more than one option. Fig. 4 presents some interesting results which suggest areas of further exploration. The profile of learners preferring interacting learning reveals over 35%, the second highest preference though very close call was the self-directed learning, which shows approximately 31%. The last

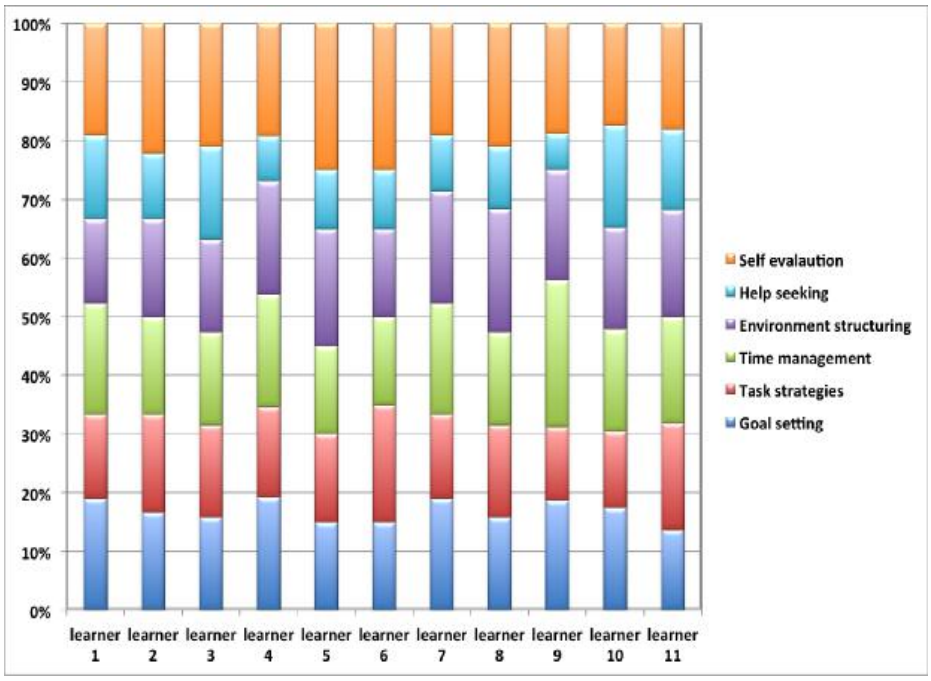

Fig. 3. Visualisation of associated responses from participants

two were instructor-led learning with 19% and collaborative learning preferences have the least with 15%. Research has shown that collaborative learning is a vital aspect of learning in a MOOC system. These collaborative learning patterns facilitate sharing of knowledge and collaboration between learners of similar learning styles [28]. However this study observed low-level of this learning habit as compared to the others. Interactive learning has been said to be in existence in the early MOOC systems, which mostly have been discussed in xMOOCs primarily centred around the learner's interaction with the course content and essentially "adopting a behaviourist learning approach" and in cMOOCs in the area of social media and interacting with peers in a connectivist learning approach [29]. This was calculated based on the number of responses received. This analysis demonstrates the level of course engagement and preference for which effective participation could be sort. The interactive learning could be in the form of discussion forums, social media, private messages, quizzes, practical exercises and feedback surveys. Most of these features were incorporated in the eLDa platform using compatible Wordpress plugins to support and motivate learning. The learners also appear to self-direct their learning process, which correspond to the result from the SRL results section.

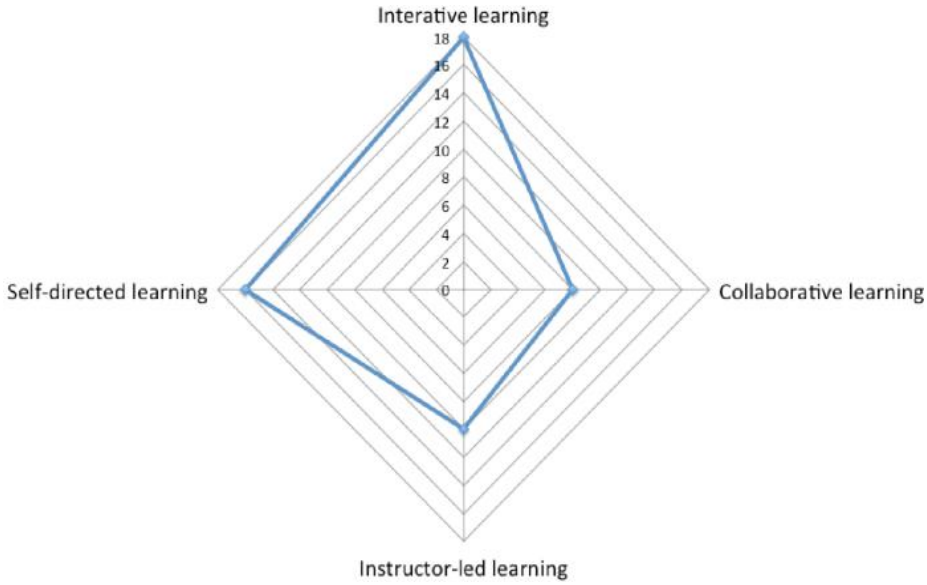

Fig. 4. Learners preferred mode of learning

4.2 Categorising SRL dimensions

We are categorising the average SRL dimensions of the learners from the two modes: self-directed and instructor-led modes. During the data collection process using the course entry survey, there are four options: (1) self-directed learning (2) instructor-led (3) Both modes and (4) undecided. In the survey response, three learners preferred the self-directed route of study, two learners preferred the instructor-led route, three learners again preferred both self-directed mode and instructor-led mode of learning and finally two learners again undecided on which route to follow during their choices of learning. In order for us to categorise the learners and to be able to obtain substantial data in the two main modes in this paper, we decided to group the modes into two major modes. We grouped the learners who preferred self-directed and both-self-directed and instructor-led modes of study into 'self-directed' category and learners who preferred instructor-led modes and those who are undecided into 'instructor-led' category. This classification was done in accordance to satisfying the requirement of one of our research questions as follows:

4.3 Research Questions

1. What levels of self-regulated learning (SRL) skills are demonstrated within a diverse MOOC learner group and are there particular areas of weakness which MOOCs should seek to improve?
2. To what extent do learners choose to direct their own path as opposed to following a guided course?

4.4 Self-directed learning

The results show that within the various dimensions of goal setting (GS), task strategies (TS), time management (TM), environment structuring (ES), help seeking (HS) and self-evaluation (SE). The level of self-regulators in these categories varies from learner to learner. The study approximate the calculated averages of the categorised dimensions into two decimal digits as seen in Table 2 and Table 3. The reason for this is to be able to identify the level of competency, in order to help us identify high and low self-regulators. In this study we decided to classify learners who score an average below 3.50 to be low self-regulators and learners with an average score of 3.50 and above to be high self-regulators (this is due to our sample size and to help with the interpretation of the results better). For example the average score of the SRL dimensions for 'learner 2' in self-directed learning mode shows high level of self-regulated learning ability in most of the dimensions except one. This indicates that learner 2 is a competent high self-regulator in all the dimensions and need to improve in help seeking ability as shown in Table 2. The implication of this shows that MOOC ability for a one-size-fits-all approach might not be fully suitable to all the learners using the idea of self-regulated learning habits. These learners choose to direct their learning, depending solely on their own ability and show low ability to interact or seek for help from other learners. Comparing this finding with other related studies show that some learners in a MOOC pattern of learning will prefer to study alone by themselves. Following the observation from the average column of the self-directed Learning (Table 2), the results indicate the earlier point and we can categorise learners 2 and 7 to be high self-regulators as their average scores of the six dimensions were 3.50 and above. The results in this mode of study also revealed learners 1, 3, 4, 5 and 6 to be low self-regulators. However, the learners in this study show some abilities and improvement in individual SRL dimensions. For example learner 1 scored high SRL skills in SE dimensions with 4.00, likewise learner 3 who also scored a high 4.50 in SE dimension. Learner 4 scored high SRL in TS and SE skills. Assessing the individual dimension basis, 'Learner 5' scored high SRL skills in GS with score of 3.50, TM with 4.00, ES with 4.00 and SE with 4.00. However, this learner overall is classified as a low self-regulators, even with this individual high scores and limitation observed in HS which is 2.00 and TS which was 2.50, on a final note learner 6 also had high TM skills (as seen in the Table 2).

Table 2. Shows high and low self-regulators in the self-directed mode using the average scores

	GS	**TS**	**TM**	**ES**	**HS**	**SE**	**Average**
Learner 1	3.33	2.75	2.50	3.00	2.00	4.00	**2.93**
Learner 2	4.67	3.75	5.00	5.00	2.00	4.50	**4.15**
Learner 3	3.00	3.25	3.00	3.67	2.00	4.50	**3.24**
Learner 4	3.33	3.50	3.00	3.33	2.00	5.00	**3.36**
Learner 5	3.50	2.50	4.00	4.00	2.00	4.00	**3.33**
Learner 6	3.00	2.25	3.50	3.33	1.00	3.00	**2.68**
Learner 7	3.67	3.00	3.50	4.00	3.50	4.00	**3.61**

4.5 Instructor-led learning

The results from the instructor-led learning indicated that there are no high self-regulators as all the learners score an average below 3.50 (seen in Table 3). This result indicated that learner 8, 9, 10 and 11 are low self-regulators. The full curve is illustrated and represented graphically in Fig. 5. However, the learners performed very high in some individual dimensions, for example learner 8 on GS and TM score 3.50 each which is classified as high SRL dimension skills, in SE score 4.00 which is also classified as a high SRL skills in this study. Learner 9 scored very high SE skills with 4.00. On the other hand learner 10 scored 4.00 on both ES and SE dimensions which is also considered as high SRL skills in these categories. Finally profiling learner 11 shows 3.75 score in TS, 3.50 in both TM and SE and a high 4.00 score in ES. The result reveals that these four learners in this instructor-led mode of study performed very high in self-evaluation skills. Therefore we can argue that they are high self-regulators in the SE category as seen in Fig. 3. However overall these learners who followed the instructor-led route of study are all classified as low self-regulators due to the fact that their average scores were below 3.50 as demonstrated in Table 3.

Table 3. Indicate high and low self-regulators in instructor-led mode using the average scores

	GS	TS	TM	ES	HS	SE	Average
Learner 8	3.50	2.75	3.50	3.33	3.00	4.00	**3.35**
Learner 9	2.83	2.50	3.00	2.67	3.00	4.00	**3.00**
Learner 10	3.00	2.75	3.00	4.00	2.00	4.00	**3.13**
Learner 11	3.00	3.75	3.50	4.00	3.00	3.50	**3.46**

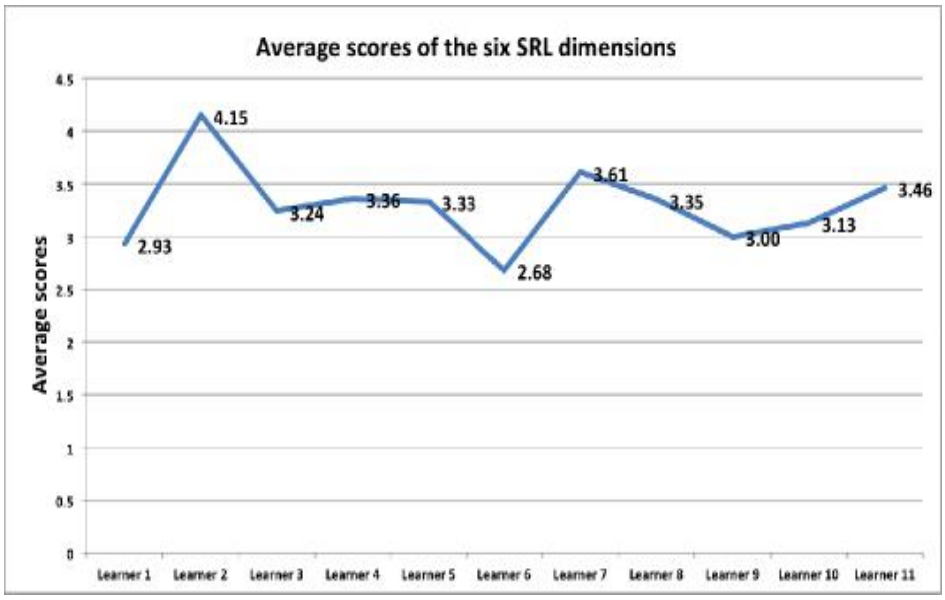

Fig. 5. Overall average score of learners from the six dimensions

Fig. 6 demonstrates the six SRL dimensions used in this study, the various modes and average scores obtained from each.

Fig. 7 illustrates the direction of the responses received from the learners. The analysis shows no uniform direction and this correlate with our initial discussion about the unique identity brought into the platform by the individual learners in this study which showcase their individuality and also helped them taking control of their studies. The results show discrepancy in the 19-item that made the MOSLQ in order to obtain the learners' SRL skills.

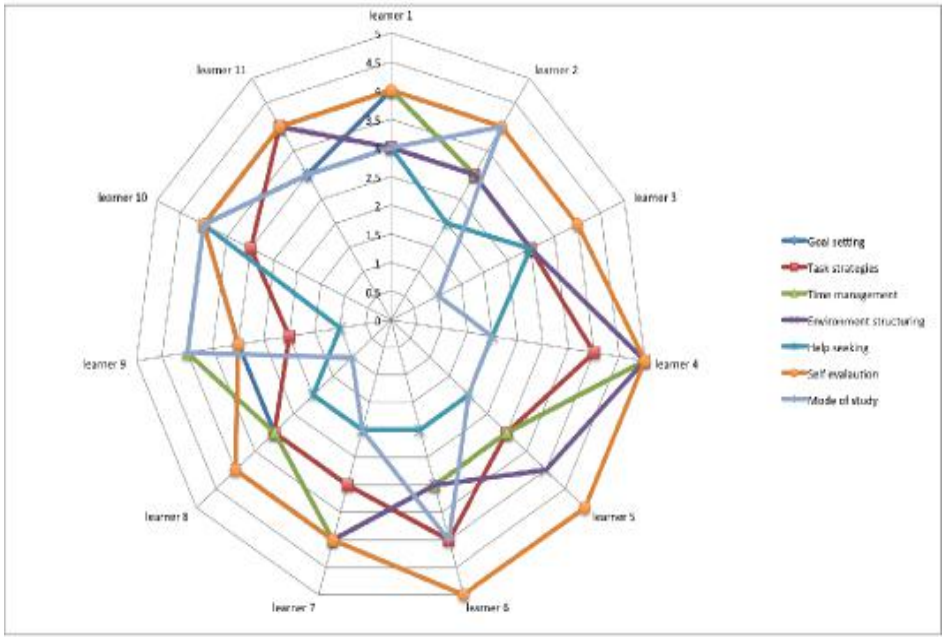

Fig. 6. Learners average SRL dimension Levels and modes of study

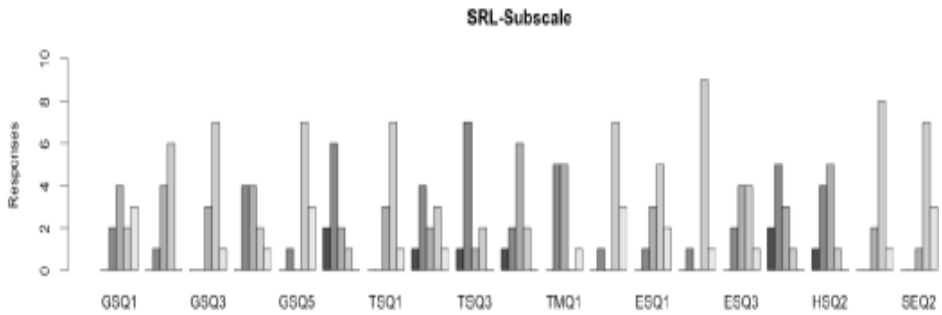

Fig. 7. Responses from the MOSLQ based on the dimensional categories

5 Discussion

Koohang and Paliszkiewicz argued that e-learning courses promote autonomous active learning activities constructed by the learners to enhance their knowledge [30]. This study investigated learners taking the initiative to control their learning and also how the novel platform tool has supported the learners in making informed choices towards directing their learning paths. The tool was able to foster the SRL skills by way of making effective use of features to support the modes of learning. Self-directed opportunities were offered to learners as well as guided opportunities which were led by the instructor. The main purpose of the instructor-led approach is to introduce lesson prerequisites that will lead the learners to specific (navigation) link containing resources which are associated to their current lesson of study. Although the tool allows flexibility of learning paths, learners are not forced to comply with the prerequisites. They can at any time switch mode of study for which they felt is suitable to the course content they were engaging with at that moment. The learners themselves decide the two main routes of study and they are free to change from one route to another with the support of the features introduced in the eLDa tool. Some studies show that appreciating new features in learning tools could be seen from the perspectives of different learners, as not all learners welcome changes in their routine e-learning environment irrespective of the benefits [31, 32].

5.1 Interpretation of results

Fig. 3 shows the learners ability of self-regulated learning. The study tried to identify the similarities and differences within the various dimensions as indicated by the learners. The following strategies expose the closely related responses as observed from the learners and how these were identified from the chosen categories which form the six dimensions in this study. We present interpretation of the six SRL dimensions in relation to the individual responses as follows:

Goal setting (GS): Goal setting is the process whereby the learners set specific task goals and planned towards achieving them. In our study we observed that learners 1, 4, 7, 9 and 10 are closely related in terms of their goal setting abilities with higher GS skills while the other group of learners 2, 3, 5, 6, 8 and 11 are closely related in their own respect with lower GS skills. However, both learners categories are different in their responses. The results shows that the first group are more better in their goal setting abilities as compare to the second group as seen in Fig. 3.

Task strategies (TS): Task strategies, as a vital aspect of SRL is the ability of the learners to plan and strategise how to achieve their set goals. The study shows that learners 2 and 8 are closely related in their task strategy ability. Learners 1, 3, 4, 5 7, 9, and 10 are similar in their task strategies with slightly high TS skills, while learners 6 and 11 are associated in their task strategies and show higher TS abilities as compare with others (as seen in Fig. 3). These results show how different learners individually planned towards executing a task. Therefore if given a task, this indicates that similar results will be observed at the end of the task and learners would be able to achieve their set goals in a similar way.

Time management (TM): Time management is another significant dimension which involves the ability or the skills of time management during study. Our research indicates that learner 9 has the highest time management ability amongst all the learners. While learners 1, 4, 7 and 11 are closely associated with slightly higher TM skills and finally learners 2, 3, 5, 6, 8, 10 also had closely related patterns in a low TM skills (as seen in Fig. 3). Time management has been known to be an important factor for online learning, because it helps learners to progress faster in their learning. Therefore in order for any learner to be able to keep up with the pace of the learning, effective time management skills must be develop as the courses are delivered either weekly or fortnightly.

Environment structuring (ES): Environment structuring is an imperative dimension in learning especially in an online or virtual environment. This is the ability of the learners to decide a suitable location for their studies in order to avoid distractions. Most learners in this study and similar studies conducted in the past said the preferred a very quiet environment either online or during an orthodox learning. Our results indicate similar learning patterns within two groups of associated learning style. Our investigation revealed learners 1, 3, and 6 showing related low ES skills while learners 2, 4, 5, 7, 8,9, 10, and 11 all show associated learning habits with higher ES skills in the category (as seen in Fig. 3).

Help seeking (HS): Help seeking is the ability of the learners to request for help in areas they have concern while studying online, either in forums or private messages to tutor. Nowadays, one of the most discussed components in MOOC today is the ability to collaborate and interact while learning which are all aspects of discussion forum. Our study shows that most of the learners preferred interactive, independent and self-directed learning typically on their own time and looking up solutions by themselves and at their own pace by researching the web. This aspect of individual self-study style has led to the low help seeking skills as reflected in our study. The result shows low help seeking skills in all the learners, however slightly improve HS skills in learners 1, 3, 10 and 11 (as seen in Fig. 3). In this dimension the scores are different in most of the cases.

Self-evaluation (SE): Self-evaluation is the process of the learner reflecting on their studies in order to understand areas they have achieved their set goals and where they have not that need revising for the future. Our results as shown in Fig. 3 illustrates a greater improvement in this area. This indicated learner 5 and 6 have the highest level of self-evaluated skills in the category. Learners 2, 3, 8 and 9 have similar levels and slightly high SE skills. Finally, learners 1, 4, 7, 10 and 11 are closely related in their self-evaluation, which reveals lower SE skills (as seen in Fig. 3). Personal reflection is of paramount as this enables the learners to understand the areas the need to put in more effort in order to improve in their SRL skills.

The main objective of this study is to understand the SRL strategies in self-directed learning routes and the instructor-led routes. This study also revealed that results were emerging from learners who have decided to switch between both modes. Thus, they are refer to 'learners that preferred both modes' of learning. These new findings will be further explored in the future.

6 Conclusion and Future Work

Although the results presented here are from a small population sample, they indicate SRL dimensions from the two main modes of learning in this study: self-directed modes and instructor-led modes. At the beginning of the course, the learners are given the options of two routes (self-directed and instructor-led) to follow in order to engage effectively with the course. When learners opted for the self-directed routes, they study the resources as they preferred and have the autonomy to move from one lesson content to another without following the prerequisites suggested [33]. But if the learners opted for the instructor-led routes, they are guided in an instructional manner with support from the lesson prerequisites. The lesson prerequisites in this case motivate the learners to build personal and decisive SRL skills while been led to study in a linear way. Our results indicate two distinct representation of the individual profile of self-regulated learning from the analysed sample: high self-regulators and low self-regulators. The results revealed that the competent self-regulators as observed mostly within the self-directed learning, show high level of self-regulated strategies in their responses with few strategies to improve. But for the low self-regulators, these learners need to improve in their self-regulated learning strategies, as most of their responses fell into the negative scale. The results also indicated the individuality of the SRL dimensions observed from the learners, which reveals the different paths that most of the learners wish to follow in their study.

In summary, we define success as not the level of participants who completed the course, but the learners meeting their expectations. A study has shown that some issues of low completion rates in MOOC might not be because the learners are not motivated to participate, but as some of the learners are engaging with the course at their own pace [34]. In this new innovative learning platform (known as 'eLDa'), completion rate was measured in relation to the learners achieving their learning goals. Further investigation of these results will be conducted in order to explore new investigation with a blended module ran within the eLDa platform tool.

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8 References

[1] Jordan, K. (2013). Mooc Completion Rates: The Data. *Availabe at: http://www. katyjordan. com/MOOCproject. html.[Accessed: 27/08/2014].*

[2] Barnard, L., Lan, W. Y., To, Y. M., Paton, V. O., and Lai, S.-L. (2009). Measuring Self-regulation in Online and Blended Learning Environments. *The Internet and Higher Education,* 12(1):1–6. https://doi.org/10.1016/j.iheduc.2008.10.005

[3] Barnard, L., Paton, V., and Lan, W. (2008). Online Self-regulatory Learning Behaviors as a Mediator in the Relationship between Online Course Perceptions with Achievement. *The*

International Review of Research in Open and Distributed Learning, 9(2). https://doi.org/10.19173/irrodl.v9i2.516

[4] Barnard-Brak, L., Paton, V. O., and Lan, W. Y. (2010). Profiles in Self-regulated Learning in the Online Learning Environment. *The International Review of Research in Open and Distributed Learning,* 11(1):61–80. https://doi.org/10.19173/irrodl.v11i1.769

[5] Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., and Schroeter, K. (2003). Enhancing Third-grade Student'Mathematical Prob-lem Solving with Self-regulated Learning Strategies. *Journal of educational psychology,* 95(2):306. https://doi.org/10.1037/0022-0663.95.2.306

[6] Puustinen, M. and Pulkkinen, L. (2001). Models of Self-regulated Learning: A Review. *Scandinavian Journal of Educational Research,* 45(3):269–286. https://doi.org/10.1080/00313830120074206

[7] Zimmerman, B. J. (1990). Self-regulated Learning and Academic Achievement: An Overview. *Educational psychologist,* 25(1):3–17. https://doi.org/10.1207/s15326985ep2501_2

[8] Borkowski, J. G., Carr, M., Rellinger, E., Pressley, M., et al. (1990). Self-regulated Cognition: Interdependence of Metacognition, Attributions, and Self-esteem. *Dimensions of thinking and cognitive instruction,* 1:53–92.

[9] Zimmerman, B. J. and Pons, M. M. (1986). Development of a Structured Interview for Assessing Student Use of Self-regulated Learning Strategies. *American educational research journal,* 23(4):614–628.

[10] Zimmerman, B. J. and Martinez-Pons, M. (1990). Student Differences in Self-regulated Learning: Relating Grade, Sex, and Giftedness to Self-efficacy and Strategy use. *Journal of educational Psychology,* 82(1):51. https://doi.org/10.1037/0022-0663.82.1.51

[11] Henderson, R. W. (1986). Self-regulated Learning: Implications for the Design of Instructional Media. *Contemporary Educational Psychology,* 11(4):405–427. https://doi.org/10.1016/0361-476X(86)90032-9

[12] Wang, M. C. and Peverly, S. T. (1986). The Self-instructive Process in Classroom Learning Contexts. *Contemporary Educational Psychology,* 11(4):370– 404. https://doi.org/10.1016/0361-476X(86)90031-7

[13] Diaz, R. M., Neal, C. J., and Amaya-Williams, M. (1990). The Social Origins of Self-regulation. *Vygotsky and education: Instructional implications and applications of socio-historical psychology,* pages 127–154. https://doi.org/10.1017/cbo9781139173674.007

[14] Rohrkemper, M. M. (1989). Self-regulated Learning and Academic Achievement: A vygotskian view. In *Self-regulated learning and academic achievement,* pages 143–167. Springer. https://doi.org/10.1007/978-1-4612-3618-4_6

[15] Carver, C. S. and Scheier, M. F. (2012). *Attention and Self-regulation: A Control-Theory Approach to Human Behavior.* Springer Science & Business Media.

[16] Zimmerman, B. J. (1989). A Social Cognitive View of Self-regulated Academic Learning. *Journal of educational psychology,* 81(3):329. https://doi.org/10.1007/978-1-4612-3618-4

[17] Zimmerman, B. J. (1989). Models of Self-regulated Learning and Academic Achievement. In *Self-regulated learning and academic achievement,* pages 1– 25. Springer. https://doi.org/10.1007/978-1-4612-3618-4_1

[18] McCombs, B. L. (1989). Self-regulated Learning and Academic Achievement: A Phenomenological View. In *Self-regulated learning and academic achievement,* pages 51–82. Springer. https://doi.org/10.1007/978-1-4612-3618-4_3

[19] Schunk, D. H. (1984). Self-efficacy Perspective on Achievement Behavior. *Educational Psychologist,* 19(1):48–58. https://doi.org/10.1080/00461528409529281

[20] Schunk, D. H. (1989). Social Cognitive Theory and Self-regulated Learning. In *Self-regulated learning and academic achievement,* pages 83–110. Springer. https://doi.org/10.1007/978-1-4612-3618-4_4
[21] Bandura, A. (1989). Human Agency in Social Cognitive Theory. *American psychologist,* 44(9):1175. https://doi.org/10.1037/0003-066X.44.9.1175
[22] Csikszentmihalyi, M. (2016). The Pursuit of Happiness. Bringing the Science of Happiness to Life. Available at: http://www.pursuit-of-happiness.org/history-of-happiness/mihaly-csikszentmihalyi/ [Accessed : 13/03/2017].
[23] McCombs, B. L. and Marzano, R. J. (1990). Putting the Self in Self-regulated Learning: The Self as Agent in Integrating will and Skill. *Educational psychologist,* 25(1):51–69.
[24] Von Alan, R. H., March, S. T., Park, J., and Ram, S. (2004). Design Science in Information Systems Research. *MIS quarterly,* 28(1):75–105.
[25] Cunningham, C. A. and Billingsley, M. (2002). *Curriculum Webs: A Practical Guide to Weaving the Web into Teaching and Learning.* Allyn & Bacon, Inc.
[26] Zimmerman, B. J. (2002). Becoming a Self-regulated Learner: An Overview. *Theory into practice,* 41(2):64–70. https://doi.org/10.1207/s15430421tip4102_2
[27] Onah, D. F. O. and Sinclair, J. E. (2015). Measuring Self-regulated Learning in a Novel e-Learning Platform: eLDa. In *Proceedings of the 15th Koli Calling Conference on Computing Education Research,* pages 167–168. ACM. https://doi.org/10.1145/2828959.2828986
[28] Onah, D. F. O. and Sinclair, J. (2015). Collaborative Filtering Recommendation System: A Framework in Massive Open Online Courses. *INTED2015 Proceedings,* pages 1249–1257.
[29] Conole, G. G. (2015). Moocs as Disruptive Technologies: Strategies for Enhancing the Learner Experience and Quality of MOOCs. *Revista de Educación a Distancia,* (39).
[30] Koohang, A. and Paliszkiewicz, J. (2013). Knowledge Construction in E-learning: An Empirical Validation of an Active Learning Model. *Journal of Computer Information Systems,* 53(3):109–114. https://doi.org/10.1080/08874417.2013.11645637
[31] Mello, L. V. (2016). Fostering Postgraduate Student Engagement: Online Resources Supporting Self-directed Learning in a Diverse Cohort. *Research in Learning Technology,* 24. https://doi.org/10.3402/rlt.v24.29366
[32] Entwistle, N. J. and Peterson, E. R. (2004). Conceptions of Learning and Knowledge in Higher Education: Relationships with Study Behaviour and Influences of Learning Environments. *International Journal of Educational Research,* 41(6):407–428. https://doi.org/10.1016/j.ijer.2005.08.009
[33] McManus, T. F. (2000). Individualizing Instruction in a Web-based Hypermedia Learning Environment: Nonlinearity, Advance Organizers, and Self-regulated Learners. *Journal of Interactive Learning Research,* 11(2):219.
[34] Onah, D. F. O., Sinclair, J., and Boyatt, R. (2014). Dropout Rates of Massive Open Online Courses: Behavioural Patterns. *EDULEARN14 Proceedings,* pages 5825–5834.

9 Authors

Daniel F.O. Onah is a Doctoral Researcher with the department of Computer Science, The University of Warwick, Coventry, CV4 7AL, United Kingdom (e-mail: d.f.o.onah@warwick.ac.uk). He received his MSc (Eng.) degree in Computer Systems Engineering with specialisation in Software Systems from University of East London, United Kingdom and he is currently a Teaching Assistant in the department of Com-

puter Science at Warwick University. He is an associate fellow of the UK higher education academy.

Jane E. Sinclair is an Associate Professor with the department of Computer Science, The University of Warwick, Coventry, CV4 7AL, United Kingdom (e-mail: j.e.sinclair@warwick.ac.uk). She received her PhD degree from the Open University, United Kingdom.

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The Students' Perspective Contribution: Rethink the Ethical Education of Engineering Students

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Fátima Monteiro
Instituto Superior de Engenharia de Coimbra – IPC, Coimbra, Portugal
fatcmont@isec.pt

Abstract—The inclusion of ethics education in engineering courses has been recognized as fundamental. However, in Portugal this training component is present only in a small number of courses. Teachers are mainly responsible for building the curriculum, but students are the ones most affected by this absence of ethics education. In this context it is necessary and important to understand students´ perspective, because their role is vital in the curriculum construction´s success. It is in this framework that this investigation listened to engineering students' voice as a factor to consider in the rethinking of engineering course curriculum in the ethics education area. This study highlights the concept that students have of engineering action, their perspective about the possibility of their courses to include ethics training and its practical implementation. This research is part of a case study and research-action. The results indicate that students are very receptive to this training component, and they consider that it should be included as mandatory in engineering courses. The results also show that students prefer a more practical training with 'prescription' characteristics and that their perspective of engineering action consequences is very limited. These results reinforce the need for ethics education that promotes a wide scope critical reflection.

Keywords—ethics education, engineering education, engineering conception, students' voice

1 Introduction

In the contemporary context, according to [1], engineering is probably the professional activity with the greatest impact on society. In fact, the presence of engineers' action is so incorporated into the day-to-day, that society has become dependent on engineering, without really being aware of its action. Even though, engineering fosters action, progress and well-being, but it also involves a dangerous and even life threatening side.

It becomes evident that the technical knowledge that engineers receive as part of their course is "powerful" [2], but raises the question of how this knowledge is being used [3]. It is not enough to provide the tools, it is also necessary to teach them how to use them for the common good [3]. For such, several authors and organizations

consider essential promoting ethical education and reflection, developing a more accurate view of how engineering can responsibly fulfill their commitment to society [1].

1.1 Presence of ethics education in the Portuguese engineering course curriculum

The foregoing is a clear indicator of the need to include ethics education in engineering courses. However, parting from the study in [4], in Portugal the presence of ethics and civic education in the engineering course curriculum is still low (22% of the courses have compulsory curricular units incorporating ethics education, but only in 7.6% of the courses it is incorporate as a compulsory curricular unit completely dedicated to the ethics education component). This data seems to indicate that higher education institutions, which teach engineering courses, do not give enough importance to ethics education to integrate this training into their course curriculum.

To understand the low presence of ethics education in engineering courses, despite the many (international and national) recommendations, it is therefore important to analyze 'why' the curriculum settings incorporate or not this training component. Such decisions are rooted in different perspectives and concepts that underlie the diversity in curriculum options.

It is necessary to take into account that historically engineering was considered neutral from an ethical point of view, therefore engineers didn't need an ethical and moral education [3]. This assumption was grounded in engineering conception as a technical action tool, as such without relevant social intervention.

However, this engineering conception didn't take into account the influence of engineering in society, neither regard their role in the humanity welfare development, and its negative effects (namely environmental). Thus, time has shown that engineering is not neutral, and that the engineer is a strong actor with social, political and environmental intervention. Nonetheless, this evidence is not yet reflected in the ethical education in most engineering course curriculums in Portugal [4].

On the other hand, some teachers argue that it is not necessary to include ethics training in engineering courses because students are adults, with their moral and ethical education already consolidated, and therefore little receptive to significant behavioural changes [7].

It is also important to note that the absence of explicit ethical education in engineering courses affects mainly their students, by denying them a full education, but also has having a negative impact on society. In this sense, [12] argues that higher education institutions form "docile" engineers who are unable to interpret the social and contemporary political reality, and are unaware of the consequences that specialized knowledge action' has on social and human actuality [13].

In this line, it can be argued that, although ethics and civic development are fundamental to society and democracy, it is also important for young people, because they can be more successful if they are involved and committed to their community and the common good [14]. In this perspective, ethics and civic education do not aim

merely at social development, but also at youth development, so this is also in the students' personal interest.

1.2 Should ethics education be integrated into the engineering curriculum?

Reference [3] and [15] argues the need for higher education to promote the ethical education of their students. According to [3], it was found that primary school education and high schools have little influence on students' political beliefs and values. This reinforces the role that higher education can and must have in order to promote the ethical development of their students. Thus, the author argues that higher education should not be limited to a database, but should promote and develop skills so that their graduates can act in the world with reflection and wisdom. With this goal in mind, the author believes that higher education should promote the moral, civic and political development, which implies the ability to develop a more sophisticated and conceptually more advanced understanding of the social complexity and of the ethical concepts, which will result in greater intellectual growth.

It is also important to note that, according to [16], moral development is part of identity and personality development. For this author, in contemporary society, the content selection process that defines the identity and is associated with ethics, moral development and motivation, only occurs in emerging adulthood that is between 18 and 25 years old. As per this data, mostly higher education students are still in this ethical and moral development phase which is of vital importance and a reference to their values and respective identity integration.

This author also states that "the level of integration of moral knowledge in identity seems to vary according to motivation" [16]. Thus, taking into account the age range of the majority of higher education students, the (theoretical and practical) ethics and moral education is relevant, in order to provide greater moral identity and integrity, the main predictors of moral motivation in future actions.

Various methods are used in higher education to promote ethics, civic and students' deontological education [3] [17] [18]. Within the engineering courses, according to [18], there are 3 main methods: Specific Curricular Units (CU); Modules that have a large amount of technical areas in the (CU), and that deal with specific cases (for example, lectures); Short training inserts in the various CU that are part of the curriculum.

However, it is necessary to consider that ethics education can be promoted as an ethical training focused on deontological ethics (based on the duties set for professional codes), and as such more individual and normative; or in a broader aspect of ethics, that is not limited to professional codes or individual action, but includes the social, political construction, incorporating the collective dimension, social and environmental in the present and in the future. The conception of engineering and of the consequences of its actions, are one of the most crucial aspects in the choice of ethics education profile for engineering students. A conception in which the role of the engineer is confined only to the technical sphere, will lead to a delimited deontological training; and a broadened conception in which engineering is recognized as having an active role in the social-political level, will lead to a wider and deeper ethics training.

1.3 Should ethics education be included in the engineering course curriculum? What do students think about this?

The following highlights the importance of the teachers' role in curriculum development and as such in the inclusion, or omission, of ethics education in engineering courses. While teachers are the main curriculum builders, students are also involved in this process [6]. On the other hand, students are the ones mainly affected by the absence of an ethics educational project within their courses. These two aspects show the need to take into account the point of view of engineering course' students about the inclusion of ethics education in their course.

According to [20], it is necessary to take into account the students' perspective to improve their course curriculum and results, it is therefore essential to speak with them, listen to their voice, because their voice has a strong transforming potential [21]. However, it is also necessary to take into account that students are often unaware of the various curricular possibilities, as well as the values and concepts underlying them [21].

It is therefore important to investigate the students' perspective on this issue: they consider ethics education has necessary or useful in the engineering courses? It should also be investigated if they are receptive to this training area or if they consider that this is inadequate, because they are already adults with moral and ethical principles? Lastly, how do they think this training field should be implemented and put into practice?

It is also important to know the concept that students have of engineering, as this will influence their perspective about ethics training. Knowing the conception of engineering and the consequences of its action allows conceiving an ethics training that is more adjusted to the students' needs.

So, the present study fits within this context and aims to listen to the students' voice in order to investigate:

- Students' conception of engineering´s action in society;
- Students' perspective on the inclusion of ethics education;
- Students' perspective on the practical implementation of ethics training;
- Students' perspective on the topics to be included in ethics education.

2 Methodological options

These objectives fall into a quantitative and interpretative perspective [19]. The framework in the phenomenological interpretative perspective is associated with the guidance that underpins the research and the object of analysis and not only with the specificity of the methods.

Thus, in the present research, a volunteer student group belonging to engineering courses that do not include ethics education in their curriculum was interviewed.

The study included ethics training and a debate, allowing students a better mastery of the topic in question, so that students aren't restricted in their expression due to the limited conceptual domain of the subject under study. It is therefore a case study [22]

which is both research and ethics education, and as such with a potential for social transformation, i.e. a research-action [23].

Given the characteristics of the study, the intention is not to make a statistical generalization of the results obtained, but instead, to hear the students´ personal voice that leads them to reflect and comment on curriculum construction. This action can already be considered a form of ethics and civic education.

2.1 Study Implementation

Twenty five polytechnic higher education engineering course volunteer students were part of this study. The choice of the institution selected for this study was based on the researcher's convenience. The courses' choice for the study was done selecting a curriculum that did not include any CU or other explicit form of ethics education, so as not to influence the students to the use of any specific form of ethics education.

The study took place in two phases: initially, before the training, the volunteer students answered a pre-training survey composed of open and semi-open questions; and in the second phase (after 8 hours of ethics training divided in two days), students answered a post-training survey with open questions, semi-open and closed (Likert scale) questions.

A content analysis procedure was used in this study to analyse the data collected (for open answers) to find out what the students' views and perspectives were. The use of content analysis is based on its ability to interpret perspectives, as well as their versatility [24]. A descriptive statistical analysis of the answers was also done.

The group was composed of 25 students, from 3 engineering areas (electrical engineering, biomedical engineering and electro-mechanical engineering) from licentiate and Masters Degree.

3 Results and their Analysis

3.1 The students' conception of engineering´s action in society

Before the training, students responded to a survey aimed at finding out their perspective on: the engineering action in contemporary society; positive and negative contributions; and about the most important values in the performance of the engineering profession.

Relative to the most important values for the practice of the engineering profession, Figure 1 shows the results in the categories identified in the responses.

From the analysis in Figure 1 it can be concluded that the students had mixed responses, values, skills and/or competences, by mentioning, for example, the "ability to work as a team", of "being proactive" or "meet objectives" as important values for the engineering. Thus, 29% of the students reported that the most important aspect is to be able to work as a team, and 22% reported honesty, responsibility and humility as indispensable values to this professional activity. Followed by professionalism and respect, in 18.5% of the responses. Also highlighted is the fact that students consider

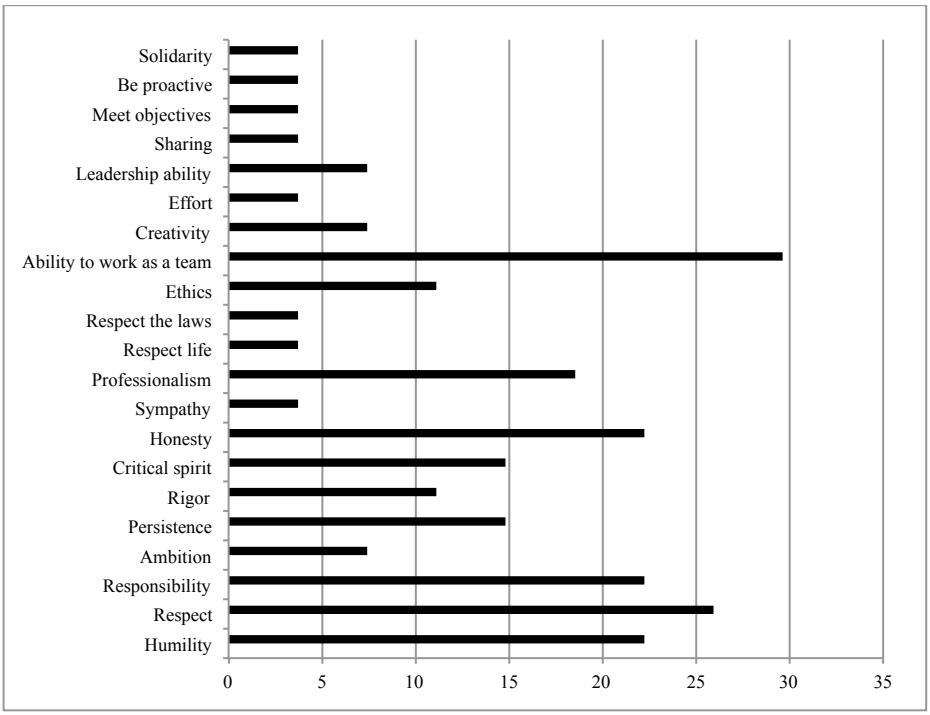

Fig. 1. The most important values in the exercise of the engineering profession as per students' opinions (% of total students).

the capacity or competence to work as a team, as being most important in the face of so many values such as honesty or justice. It can also be stressed that 7.5% of the answers considered that the most important value for an engineer is, ambition, and that 3.7% consider it important that the engineer be "meet objectives". Most of the answers submitted are indicators of the engineer's perspective as a technical instrument [26], and as such to be technically competent, and not as an actor who intervenes in the social construction, and as such without the need of ethical and moral values.

To better clarify what perspective students have of engineering, they were asked to choose the phrase that best defined the importance of engineering in society. These results show that the majority of students (52%) identifies themselves with the ideology of progress [26], which gives engineering the role of being the engine behind development and progress. The second most selected option (22%) corresponds to the belief in the technical and scientific development ideology [26], in which this is seen as a good in itself. The option least selected (11%) corresponds to the ideology of economic development, in which engineering is seen as fundamental to the entire production process [26]. The option corresponding to the ideology of creativity was chosen by 15% of the students. Most answers highlight not only the belief in the progress ideology, but expressed as well the belief that the potential of engineering is limitless.

Students were also asked about the image that society has of engineers. 80% of students considered that the image is very positive and only 20% consider it a negative image. Some of the answers demonstrate the extremely positive belief that the students themselves have of Engineering: "they are well regarded by society as it is a profession that creates many jobs and brings to the citizens new technologies and wellness"; "I see them as people in our society that help promote the development of the country and solve the practical problems of our society"; "these are people with a lot of knowledge in their area, with huge capabilities to contribute to the progress and development of technologies or even to humanity". These responses also show their belief in the ideology of progress.

14.8% of the students did not reply to the open question about the best impact/influence of engineering in society. From the responses obtained a set of 10 categories was identified, the results are shown in Figure 2.

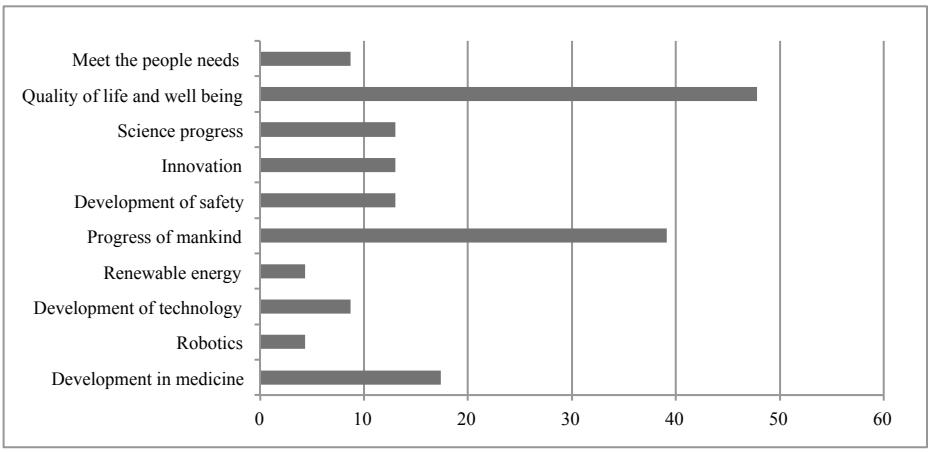

Fig. 2. Answer to the open question about the best impact/influence of engineering in society (% of total students).

The category most referred to where engineering is making the strongest contribution to society was quality of life improvement and well-being (47.8%). Some answers highlight the high expectations of students: "engineering has a great impact on society, as it allows increasing the standard of living and welfare of the people, regardless of the area or the planet where they are living"; "I think engineering has an impact throughout society, which would not even exist without the contribution of engineering"; "the greatest contribution of engineering is to turn fiction into reality". These replies strengthen the perspective of the belief in the progress ideology and the unlimited nature of engineering potential.

The students were also asked about what the worst impact/influence of engineering on society was. From their answers 13 categories were identified which are shown in Figure 3.

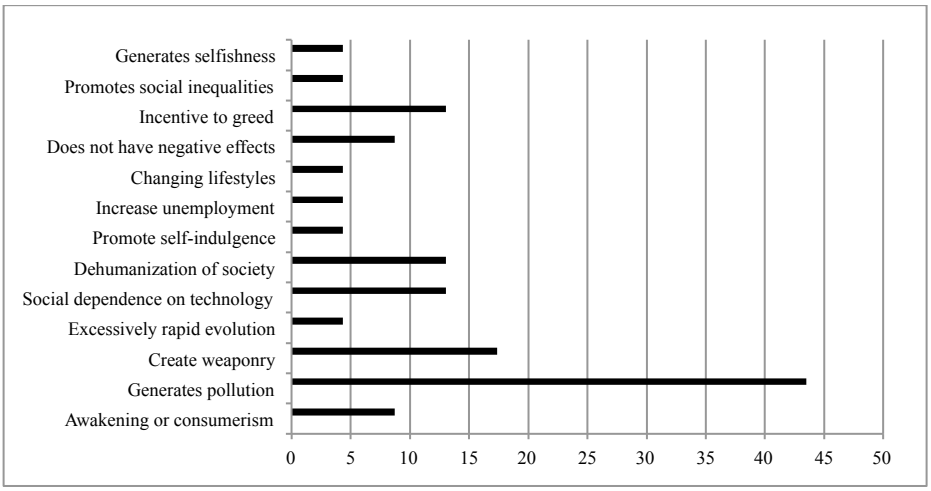

Fig. 3. In the students' opinion, what is the worst impact/influence that engineering has on society (% of total students).

The response of 43.5% of the students referred to the worst impact, as being pollution, followed by armament (17.4%) and 13% of the choices were social dependence on technology, the dehumanization of society and an incentive to greed. It should also be noted that 8.7% of students reported that Engineering has no impact or negative influence on society.

One of the answers absolves engineering of any wrongdoing: "the worst impact is not created by engineering, but by the people who channel their knowledge to harm humanity". Another answer shows a more complex association between different levels of impacts that interrelate: "I think engineering leads to evolution, which awakens the consumerism and ultimately creates inequality, because the developments are always more accessible to social groups with higher purchasing power; and more and more people tend to think of evolution as a way to get rich and not to help others ".

In synthesis, they were asked if they thought engineering contributes to a "better world" and if so how. The answers highlight the belief in the supremacy of Engineering: "without a doubt. Where would we be today without engineering? Engineering came to bring a great development and make daily life a lot better for all inhabitants of the planet"; "yes, without a doubt, its contribution brings people happiness, making them dream"; "yes, it increases time and quality of life, facilitates rapid knowledge sharing and information and all this makes the world a better place"; "yes, with engineering its possible for humanity to evolve". However, some responses recognize some doubts: "engineering can create a near-perfect world, but people have a duty to continue to be human and not let everything turn into machines"; "I think so. At a time when there are actual facts that the world is getting worse at our expense, engineering is being redirected to what is correct for the world, rather than to what is comfortable for us. "

One reply highlights the belief in the neutrality of Engineering: Engineering "does not contribute to a better or worse world. Contributes above all to people´s needs ".

3.2 Students' perspective on the inclusion of ethics education

Before and after training students were asked what they thought about the possibility of including ethics education in engineering courses. Results show that before training, the majority (89%) of the students thought this training component should be included in the curriculum, and some of them state that it should not only be in their course, but in all higher education courses. However, 11% of students stated that they did not know because they consider themselves unaware of the matter.

After training, the results show that 100% of students consider that ethics education should be part of their course. On one hand, the training clarified that some students had doubts about it, on the other hand it increased the degree of belief that many students, manifested through expressions and answers that went far beyond a simple "Yes" (which was the most frequent response prior to training). This strengthening conviction was expressed by statements such as: “Undoubtedly yes”, “yes, no doubt“,” yes, it´s a must!”,”Yes, I think it is a fundamental curricular unit”, ”Yes, without a doubt”.

3.3 Students' perspective on the practical implementation of ethics training

As mentioned in the introduction of this study, the recognition of ethics education being needed in higher education courses seems to be quite consensual, but there is no consensus concerning the practice of such training [7]. Thus, the students (who are the ones who have the most to lose or gain in this process) were asked about the practical way this training should be implemented. This question was asked before and after training.

From the results it appears that prior to training 48% of the students thought that this educational component should be incorporated into the curriculum as a compulsory CU. The remaining students' answers were broken down as follows: 7.4% believe it should be an optional CU; 14.8% think it should be extracurricular training; 22.2% thought it should be as some form of short training; and 18.5% believe it should training distributed throughout the various technical CU (note that the sum of these values exceeds 100% because some students had more than just one answer).

After the training, all options decreased significantly, except the conception of ethics education based on a compulsory CU, which increased to 52%.

3.4 Students' perspective on the topics to be included in ethics education

During the training six topics were addressed: Ethics and moral concepts; Framework and ethics, historical evolution; Contemporary ethics; Engineering action consequences on society and the environment; “Ethics for engineers” [1]; Professional Code of Ethics (from engineering professional entities).

After the training, the students were questioned about the training usefulness for their personal life and their future professional life. The results show that none of the students feel that the training was useless or of little use. As per whether or not it was useful for their personal life, 24% considered it fairly useful and 76% very useful.

Pertaining to how useful it was for their future professional life, 8% considered it fairly useful and 92% very useful.

In order to investigate whether the training in question had brought something new to students, they were also asked if the training allowed them to discover, learn or understand any subject they deemed relevant. 60% of the students answered that the training allowed them to discover, learn or understand some issues they considered relevant, and 40% that the training allowed them to discover, learn or understand many relevant issues.

As to better understand what topics students considered most relevant to ethics education in engineering courses, students were asked which topics they would exclude from the ethics education, and what topics should be included. The answers are presented in Figure 4.

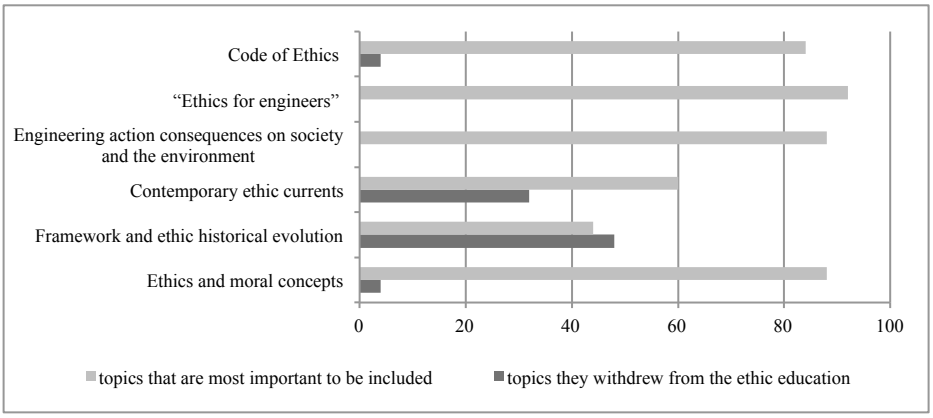

Fig. 4. students answers (% of total students): "From the topics covered in the training, which would you remove and which ones would do you consider most important?" [27].

The results show that students consider all topics are important, and only in one case - Historical ethics framework - the number of those who removed this from the training was greater than those who considered it important. However, the difference between those who would exclude it and those who consider it important is only 4%, which corresponded to one student´s answer.

It should also be noted that the least valued topics are the most theoretical, and the most valued are those that demonstrate the practical application of ethics to real engineering case scenarios. This fact is consistent with the profile of engineering students that, in general, value more the practical component of their course. In this sense, students often expect (and are used to) follow rules and procedures that act as "prescriptions" for action, not to reflect and critically and theoretically analyze multifaceted and complex issues.

Thus, it is necessary to take into account that, in general, engineering courses do not encourage reflective practice, and that, on the contrary, often favor knowledge' memorization and mechanization [25], in the application perspective and not of reflection. This increases the difficulty of students in broadening their vision beyond the

purely technical application (works or does not work) to see their actions in the broader context of society and environment (ethical, political, environmental and social relations and consequences).

Students were also asked about the negative aspects of the training and improvements to be implemented in future editions. The main suggestions were that the number of examples and discussion of “real life” case studies ("Increase analysis / case discussion of real life (what you would do if....)") should be increased. This aspect is consistent with the perspective of a "prescription" training type already mentioned and the indication that it should have less theoretical issues.

Another aspect mentioned was the fact that the training was very short (8h) and being that it was so limited there was no time for all participants to share their views ("I think it should be mandatory). If it is not possible, at least it should be longer so as to give students more time, to share their opinions, which will create an opportunity for these issues to be further discussed. ").

4 Conclusions

The results show that the conception of engineering action that students defend is based mostly on the ideology of progress, and that the action of engineering is regarded as essentially positive and unquestionable. They also consider that the engineering potential is unlimited and features a limited awareness of the possible consequences in the various social-environmental areas. In this context, their answers were limited to the most obvious consequences: quality of life improvement/well-being as a positive effect, and pollution/armament as negative. However, only a very reduced number of students referred to the fact that the benefits (in terms of quality of life and well-being) are not accessible to all people, or the nefarious connection between the economic exploitation of the technology created by engineering and the social and moral behavior change.

These aspects reinforce the need for students to have ethics education, in order to broaden their awareness of the limitations and potential social-environmental consequences of the various ideologies that are associated with engineering, promoting the recognition of its role within the complex contemporary sociopolitical construction. Thus, these results reinforce the need for engineering students' ethics education to promote critical reflection on the action of engineering and on the concessions that are associated with it, for example, through the study and reflection of engineering history.

The results also show that the engineering students who participated in this study consider it necessary to incorporate ethics education in engineering courses, as a compulsory Curricular Unit.

It also shows that some students had doubts about this issue, since they do not consider themselves well-informed about the subject in question. In this sense, the training implemented during the study provided the students’ with clarification and exemplifies some important themes that can be incorporated into the ethics education of engineering students. The results show that this training was a clarification that result-

ed in students' greater conviction about the importance of incorporating ethics education in the engineering curriculum, and increased the demand for a mandatory ethics education in Curricular Unit format.

Thus, these results question the argument that higher education students, as adults, are unreceptive to this training area [7]. This aspect is also highlighted by the voluntary and significant students' participation in the proposed ethics training referred in this study.

The results also show that students believe that the ethics education domain is useful for both: their personal life and professional future. The students considered the ethics education they attended as a learning opportunity for relevant issues, which reinforces the conclusion that they are receptive to ethics education, and that it can bring learning opportunities, reflection and "broaden horizons", and as such, have the potential to be a strong personal and professional ethics development tool.

The results also indicate that the students in question value a more focused training in practical cases and its discussion, and place less importance on the theoretical foundation component and understanding of the ethical currents. This indicates a "prescription approach" and less of a theoretical / reflective perspective. This view may be rooted in the engineer conception of being just a technical tool, and not as strong sociopolitical co-builder. In this sense, the central concern is more focused on a concrete, practical issues response, than a "sense of the world" reflection that theoretically justifies a particular direction for social construction evolution. This result is in accordance with the concept and perspective that engineering students have expressed, which does not evidence a potential action at the sociopolitical level, but only technical and at the economy and well-being level. These results reinforce the need of rethinking engineering education that incorporates the ethical education of its students and that promotes a wide critical reflection enabling them to become aware of the role that engineering plays in different domains: social, political, economic, environmental, moral, etc.

Given the small group size and the fact that 76% of the study participants were male and predominantly from the electrical engineering area, it will be necessary to continue the study with participants from both genders and different engineering areas.

5 References

[1] Rego, A. and Braga, J. (2014). Ética Para Engenheiros. 3ªed, Lisboa: Lidel– edições técnicas.

[2] Young, M. (2010). Conhecimento e Currículo: do socioconstrutivismo ao realismo social na sociologia da educação. Porto Editora.

[3] Ehrlich, T. (2000). Civic Responsability and Higher Education. Americam Council on Education e Oryx Press.

[4] Monteiro, F., Leite, C. and Rocha, C. (2016). Ethics and Civic Education in the Curriculum of Engineering courses in Portuguese Higher Education System. 8th International Symposium on Project Approaches in Engineering Education (PAEE) and 14th Active Learning in Engineering Education Workshop (ALE) Proccedings.

[5] Durham, E. (1989). A Autonomia Universitária: o princípio constitucional e suas implicações. Núcleo de Pesquisas sobre Ensino Superior - Universidade de São Paulo.
[6] Leite, C. (2011). Questões do currículo no ensino universitário: O que distingue a organização e o desenvolvimento do currículo deste nível de ensino?. In Leite, C., Pacheco, J., Moreira, A. and Mouraz, A. Políticas, Fundamentos e Práticas do Currículo. Porto Editora. pp 278-287.
[7] Oliveira, L. and Afonso, J. (2016). A ética como objeto de ensino. In Almeida, F., Seixas, A., Gama, P., Peixoto, P. and Esteves, D. (coord). Fraude e Plágio na Universidade. Coimbra University Press. pp 145-152. https://doi.org/10.14195/978-989-26-1123-5_6
[8] Leite, C. (2003). Para uma Escola Curricularmente Inteligente. Edições ASA.
[9] Shay, S. (2014). Curriculum in higher education: Beyond false choices. In Gibbs, P. and Barnett, R. (Eds.).Thinking about Higher Education. Springer International Publishing. pp139-156. https://doi.org/10.1007/978-3-319-03254-2_10
[10] Driel, J., Verloop, N., Werven, H. and Dekkers, H. (1997). Teachers' craft knowledge and curriculum innovation in higher engineering education. Higher Education Journal, 34 (1). pp105-122. https://doi.org/10.1023/A:1003063317210
[11] Rovira, J. (2003). Prácticas Morales - Una Aproximación Moral. Ediciones Paidós Ibérica.
[12] Nussbaum, M. (2014). Educação e Justiça Social. Edições Pedago.
[13] Giddens, A. (1998). As Consequências da Modernidade. Celta Editora.
[14] Levine, P. (2015). The Future of Democracy: Developing the Next Generation of American Citizens. Tufts University Press.
[15] Estrela, T. (2010). Ética e pedagogia no ensino superior. In Leite, C. (org.). Sentidos da Pedagogia no Ensino Superior. CIIE/Livpsic. pp11-27.
[16] Ferreira, J. (2013). O Que Nos Leva a Ser Morais? A Psicologia da Motivação Moral. Climepsi Editores.
[17] Jacoby, B. (2009). Civic engagement in today's higher education: an overview. In Jacoby, B. (org). Civic Engagement in Higher Education: Concepts and Practices. Jossey-Bass Books. pp 5-30.
[18] Davis, M. and Feinerman, A. (2012). Assessing graduate student progress in engineering ethics. Science & Engineering Ethics, 18(2). pp 351-367. https://doi.org/10.1007/s11948-010-9250-2
[19] Lessaed-Hérbert, M., Goyette, G. and Boutin, G. (1994). Investigação Qualititiva: Fundamentos e Práticas, Lisboa: Instituto Piaget.
[20] Rubin, B. and Silva, E. (eds) (2003). Critical Voices in School Reform: Students Living through Change, Routledge.
[21] Rudduck, J. and Flutter, J. (2003). How to improve Your School: Giving Pupils a Voice. Continuum International Publishing.
[22] Yin, R. (2001). Estudo de Caso: Planejamento e Métodos, 2ªed, São Paulo: Artemed Editora.
[23] Nunes, R. (2006). Investigação-ação e Inovação em Educação, Edição do autor - Relatório apresentado ao concurso de Professor Associado da FPCEUP.
[24] Guerra, I. (2010). Pesquisa Qualitativa e Análise de Conteúdo: Sentidos e Formas de Uso. Editora Princípia.
[25] Marchand, H. (2008). Desenvolvimento intelectual e ético em estudantes do ensino superior – implicações pedagógicas. SÍFIFO – Revista de Ciências da Educação, n.7. pp 9-17.
[26] Dubreuil, B. (2007). Imaginaire Technique et Éthique Sociale. Instituto Piaget.
[27] Monteiro, F. (2016). Include ethics education in the engineering curriculum – the students' perspective. Proceedings of CISPEE2016- 2nd International Conference of the Portuguese Society for Engineering Education. https://doi.org/10.1109/CISPEE.2016.7777726

6 Author

Fátima Monteiro (fatcmont@isec.pt), since 1995 is professor in the Instituto Superior de Engenharia de Coimbra (www.isec.pt) (Coimbra Engineering School, Portugal). Have an academic background in Electrical and Computers Engineering, in Education and Adult Training and Education Science (Universidade do Porto). The current interests of research are within the interconnection between engineering education, philosophy and educational sciences, mainly in the field of ethics and civic education of engineering students'; in the conception of the engineer as an social and political actor; in the assessment of learning and in the designed and implementation of curriculum in engineering courses.

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ICT-based Innovation and Employability for Women

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Marios A. Pappas
National Center for Scientific Research "Demokritos", Agia Paraskevi, Attica, Greece
mpap@iit.demokritos.gr

Yannis Papagerasimou
National Center for Scientific Research "Demokritos", Agia Paraskevi, Attica, Greece
ypapa@iit.demokritos.gr

Athanasios S. Drigas
National Center for Scientific Research "Demokritos", Agia Paraskevi, Attica, Greece
dr@iit.demokritos.gr

Dimitris Raftopoulos
National Center for Scientific Research "Demokritos", Agia Paraskevi, Attica, Greece
dr@iit.demokritos.gr

Pantelis Nikolaidis
National Center for Scientific Research "Demokritos", Agia Paraskevi, Attica, Greece
dr@iit.demokritos.gr

Abstract—The utilization of ICTs in creating new jobs and eliminating gender based inequalities in employability and entrepreneurship, employs increasingly more researchers, governments and organizations around the world. In this article we analyze the current situation regarding the impact of ICTs, social networks and media on creating new opportunities for the employability of women. We also present the new market requirements, the new e-skills that will be acquired by women in order to take advantage of new labor market opportunities. Finally special reference is made to new trends in women's entrepreneurship as well as the supportive role of ICTs.

Keywords—ICT, Female Entrepreneurship, ICT-based Innovation, ICT-skills, Employability for Women, Labor Market.

1 Introduction

Today, it is commonly accepted that digital literacy [1]constitutes a global priority. The rapid development of digital technologies, in particular of Information and Communications Technologies (ICTs) worldwide, creates major challenges for smart,

[1] The term *Digital Literacy* describes the utilization and comprehension of information in the digital age (Gilster, 1997)

sustainable and inclusive growth. ICT tools and services generate opportunities for growth and investment in developed and developing countries. New professions are created, based on these technologies, as well as existing professions adapt to them, leading to the transformation of the old economy. The integration of ICTs into large, medium and small enterprises leads to upgrading of production, design and marketing, while providing opportunities for innovative practices.

Digital economy as well as ICT sectors grow seven times faster than the rest of the economy and is therefore one of the seven key flagship initiatives of the Europe 2020 strategy (European Commission, 2011). Having to face these new standards in the global labor market, governments, businesses and employees should adapt and get ready to take advantage of the upcoming development of the ICT sector. It is observed that despite the high unemployment levels and the economic crisis, there is a lack of qualified staff in ICT.

At the same time as most studies indicate, Europe faces an increasingly widening gap of digital skills. This is subsequently an important cause for concern, just because of the strategic importance of Information and Communication Technologies (ICTs) to achieve the EU's objectives in relation to a more competitive international economy. This situation is worrying but also promising for the future of young skilled employees, especially from vulnerable groups who may have disadvantages in the labor market so far.

In addition to the existing problem of lack of ICT executives in the European labor market, there is also the problem of low representation of women in occupations related to ICTs. It is a great contradiction that while research indicates that strong female presence in business leads to more effective decisions, and women demonstrate greater creativity and efficiency, however they are only 30% of workers in ICT jobs in Europe and only 9% of the applications have been created by women.

According to the European Commission, inclusive growth refers to the creation of jobs (especially for women, young and older workers), the investment in skills and lifelong education in order to help people of all ages to anticipate and manage different situations, the modernization of labor market and welfare systems and finally the equitable distribution of the benefits of growth to all European Union countries.

In this article we were based on the modern literature to describe and analyze the new working environment emphasizing on the use of ICT tools (web and social media), to investigate and study the major European initiatives and best practices to strengthen the role of women in the field of ICTs and to launch women in digital skills, as well as to investigate the role of ICTs on women entrepreneurship and innovation and their utilization for the new trends of employability.

In the labor market nowadays, women and men have the same privileges and the same opportunities?

Which are considered as the most important employability skills prevailing in today's digital age?

The utilization of ICT could create new jobs and opportunities for entrepreneurship for women?

This research was based on the review of the current literature on the basis of published studies and reports of the last years. Bringing together all the existing

knowledge of the subject, we assessed and linked the results of individual studies in order to draw any conclusions and proposals for the future as regards to the ICT-based employability and entrepreneurship for women.

2 Gender and Employment

Despite the existence of institutionalized provisions and laws on gender equality, every day there are observed actions of discrimination against women in the workplace. The legislative equality sometimes contradicts daily practice, as there are essential gender-based distinctions, as regards access to the labor market, remuneration policy and benefits, as well as career development and labor relations.

In many cases, women face prejudice and distrust in their working environment, even if they have more qualifications than their male colleagues. As a result of these prejudices and stereotypes, women rarely possess positions of high responsibility, as management positions.

2.1 Glass Ceiling

Despite the fact that in recent years women claim their share in the labor market on equal terms, most business executives in key positions are men. Glass ceiling could be defined as the reason why there is a limited participation of women in positions of responsibilities, such as managers, human resources and other posts which demand executive job (Arfken et al, 2004). Reduced participation of women in decision making could be found in both the public and the private sector and also in politics.

The belief that exists at a large portion of the labor market is that women lack in leadership skills in comparison to men, is a factor for the reduced women's assess to positions of expanded duties. Moreover the behavior required in the role of the leader is considered incompatible with the beliefs of the people on the desirable female behavior. According to Jackson and O'Callaghan (2009), female employees face 'the lack of expatriate assignments and international experience' that prevents their promotion to the highest levels of the corporate hierarchy.

The first step that young women should follow in order to break the glass ceiling is to set goals and make the effort to reach them. They should detach themselves from stereotypes and learn from senior women in management (Baumgartner and Scheider, 2010).

2.2 Remuneration Policy

Indicative of the ongoing gender based differentiation is the pay gap between women and men. This gap is a result of the disparagement of women's skills and professional qualifications as well as the difference in hourly compensation depending on the quality of work. Mandel and Shalev (2009) highlighted the important role of wage inequality within classes which determines the women's exclusion from positions with high responsibilities. According to figures published by the General of

Justice of European Commission in 2014, women across the European Union earn on average around 16.4% less than men, despite the fact that for years there are voted provisions in order to close the gender pay gap (European Pact for Gender Equality, 2011 and Actions on gender equality agreed between the European social partners, 2005).

According to the U.S. Bureau of Labor Statistics, in 2015 the median gap in median annual earnings was 20%, as the median annual earning for full time male employees in United States was 51,212 compared to 40,742 for female employees. According to the Workplace Gender Equality of the Australian Government (2016) men are paid 17.3% more than women, as their full-time average weekly earnings are 277.70 $ more than in women.

2.3 Part-Time Jobs

The economic recession in Europe and the comparatively high cost of the permanent staff for companies, contributed to part-time work, which appears in the form of fixed term contracts or sometimes in the form of 'rental' employees.

The Dutch part-time employment model is considered to be the new trend for young women. Nowadays, 60% of employed women in Netherlands work 30 hours or less. The propensity to work part-time significantly increased for women born after the 1950s (Bosch, Deeten & Euwals, 2010). There are two conflicting viewpoints about women working at part time jobs. On the one hand, part time jobs could be accused of under-utilization of highly educated women. On the other hand part time jobs provide an opportunity for women to work less and to be able to deal in parallel with other things, such as raising their children (Booth and Van Ours, 2010).

2.4 Family and Job Balance

A question that concerns young women in recent years is "Should I choose Career or Family?" Continuously increasing demands of the labor market, competition, long working hours, stress and pressure, are only a few factors which contribute to family and career to be considered as two incompatible concepts. However, numerous examples of modern women which managed a balance between work and family, weakened this belief. Women have to find on their own solutions in order to integrate their family and career role. According to successful women's perspectives, family should be the first priority, as mothers should be involved in their children's activities and life, but there is no need to spend the whole day with them (Cheung and Halpern, 2010).

The successful combination of work and family is greatly influenced by the conditions of work, as well as by the quality of life of each individual (Laurijssen & Glorieux, 2013). Vanderpool & Way (2013) stated that employees who face difficulties to balance career and family were more likely to present job anxiety and as a result to drop their performance or to give up their jobs.

2.5 Sexual Harassment

Sexual harassment is considered to be a major barrier for career development of women and may be accompanied by decreased job satisfaction, lower organizational commitment, or increased withdrawal behaviors. An incident of sexual harassment in the workplace could cause disturbances in physical and mental health and in some cases post-traumatic disorders (Willness, Steel & Lee, 2007). According to the report of the European Union Agency for Fundamental Rights (2014), 'sexual harassment is more commonly experienced by women in the highest occupational groups, as 75% of women in the top management category have experienced sexual harassment in their life time'.

Companies should spend time and resources in order to make serious policies against sexual harassment. In order for these policies to be effective, companies should organize monthly meetings, sexual harassment training sessions and take immediate action for any occurrence becomes known (Roberts & Mann, 1996). Lim & Cortina (2005) proposed that eliminating all elements of a hateful work environment could be more effective, as there is possible correlation between general incivility and sexual harassment.

3 New Trends in Employability Skills

3.1 e-Skills

Nowadays, information and communication technologies evolve rapidly. Lack of skilled personnel in ICT could result in loss in competitiveness of the economy. European countries should invest in education and adapt their educational system in order to prepare employees for the ICT business, as well as for the e-Government base (Doucek, 2011).

Employees and unemployed who wish to join the workplace should keep up with the times and constantly train their ICT skills in order to benefit from the new business opportunities in the evolving labor market (Várallyai & Herdon 2010). Based on current data, companies require from employees more than a specific job skill, as skills in particular technologies are considered essential in most jobs (Gourova, Antonova & Nikolov 2006). Governments, educational institutions and industries should contribute to the educational process in order to enable new employees to meet the demands of the labor market.

Training in ICTs could help women to develop basic digital skills, overcome language barriers and gain confidence in their ability to learn new things (Garrido, Sullivan & Gordon, 2010). Recent studies (Felstead, Gillie, & Zhou, 2007; Riley, 2007) reveal the relationship between ICT skills - employability and especially on the effect of computer skills on compensation and opportunities for upward mobility. In particular, a study by Green et al. (2007) shows that computer skills have significant impact on pay (5.3% and 6% for men and women, respectively).

3.2 e-Mentoring

E-mentoring is a process through which specialized and experienced professionals teach, counsel and give practical guidance based on their knowledge to newcomers in the labor market. However e-mentoring could be based on bidirectional mentoring and information exchange, for example between colleagues where there will be mutual benefit from this relationship (Bierema & Merriam, 2002).

E-mentoring seems to be a significantly useful tool for aspiring women managers, which is able to transcend boundaries such as geographical, demographic, functional or hierarchical, giving access to more and more people (Headlam-Wells, 2004). In addition to the development of specific skills, e-mentoring may contribute so that mentees gain inspiration and take psychological advantage for their career and personal development (Headlam-Wells, Gosland & Craig, 2006).

4 Labor Market Trends

In developing countries seeking sustainable economic development, ICTs are considered a means for the gradual disengagement of the economy from low-value-added primary sectors such as agriculture. However, a business (economic) model which was successfully implemented in a developed economy, might not lead to the same results in a developing economy. Investment in ICT for developing countries should aim to counterbalance the disadvantages of the economy and create new products and services to join actively the global market place, while developed economies should take advantage of ICTs to improve the existing products and services (Roztocki & Weistroffer, 2009).

More and more companies are investing in social media in order to strengthen their influence. As the social networking sites such as Facebook, Twitter and LinkedIn have become very popular among all age groups, companies create brand fan pages in order to enhance the relationship with their customers and increase their popularity. Ease of use and interactivity of digital tools enable customers to evaluate their experience after each purchase and in this way help the firm as well as other consumers with their comments (De Vries, Gensler & Leeflang, 2012). In an effort to create effective social media campaigns, companies should take into account that people in their majority use the social media as entertainment tools and as a way to escape from daily problems. Therefore, campaigns should be differentiated from those of other brands and exploit all necessary means to attract customers. Furthermore, effective social media campaigns should follow the new market trends and meet current consumer demands in order to result in band loyalty from the perspective of customers (Erdoğmuş & Cicek, 2012).

As expected, current economic conditions affect the investment in ICTs. Organizations which in periods of economic growth invest in the ICT sector, in times of recession and uncertainty reduce this expenditure (Underwood & Khosrowshahi, 2012).

5 ICT Sector Development

The term ICT sector comprises all professional fields concerning the research, the design, the development and the management of IT products and the telecommunications, as well as the software development industry. According to the 2010 report on R&D in ICT in the European Union (Turlea, 2010), the ICT sector could be classified into two subsectors:

- *Manufacturing,* containing IT equipment, Telecom and Multimedia equipment, as well as measurement instruments
- *Services,* which could be computer services and software or telecommunication services.

ICT services could be produced by the companies themselves or be provided through other operators. Expected benefits from the incorporation of ICT services may be the increase in productivity and the upgrading of products or services provided, acceleration and facilitation of specific processes such as communication with external associates, and finally, the securing of funds and resources (Hollenstein, 2004). In order to achieve organizational success, there are required ICT projects with a detailed project plan for the desired outcomes (Bygstad & Lanestedt, 2009).

The ICT sector could contribute decisively to the organization and internationalization of Research and Development (R&D), establishing ICT R&D centers in emerging economies and hence accelerate the growth and innovation for the industry (Hanna, 2010).

The ICT sector is one of the most important areas for the global economy, due to the growing demand for automation and digitization of both the private and public sector. Reduced cost of computer technology has led many companies and organizations to the computerization and the replacement of low qualified workers performing routine tasks. These workers have passed to service occupations which due to the increased required skills are difficult to be automated (David & Dorn, 2013). The ICT sector is one of the most innovative and productive in the European Union. Due to the fast growth of the ICT sector and the high competition worldwide, innovation in ICT is critical for Europe's competitiveness. The integration of ICTs in the public sector and the utilization of ICTs for some major challenges in EU such as the ageing population, the improvement of living standards, as well as the upgrade of health and environment services are of paramount importance (Wintjes & Dunnewijk, 2008).

Colombo, Croce & Grilli (2013) evaluated the impact of the adoption of broadband Internet technology on the productivity of small and medium enterprises (SMEs). According to the results of the study, SMEs could benefit from the adoption of selected advanced broadband applications only under specific conditions, always depending on the sector in which they operate and the condition to make strategic and organizational changes.ICT businesses will have to adjust their strategy in order to reap the benefits of the wider development of the industry.

6 Entrepreneurship

The growing interest in women's entrepreneurship in recent years is due to the general trend of the global economy to entrepreneurship, as well as to the perception that female led micro and small enterprises could lead to significant effect on overall household well-being (Minniti & Naudé, 2010). The size of the public sector has a significant impact on entrepreneurship rates for both sexes, but the negative effects are more highly visible on female entrepreneurship. Furthermore, some restrictions in relation to the female freedom of movement contribute negatively to the aspiration of women to take care of business (Estrin and Mickiewicz, 2011).

Even if gender equality and women empowerment are consistently promoted, male or female stereotypes could affect a woman's decision to become an entrepreneur. Policy makers should focus on how to eliminate such beliefs in order to encourage women's entrepreneurship (Kobeissi, 2010). Women, at a much greater proportion than men, consider that values such as respect, initiative and achievement, are crucial in the decision to become entrepreneurs (Terrell & Troilo, 2010).

Women face various problems associated with entrepreneurship, such as marketing problems due to poor location of their unit or through competition from large units, financial problems like shortage of funds and health problems may be due to lack of rest (Nayyar et al, 2007).

According to the Statistical Data on Women Entrepreneurs in Europe (European Commission, 2014) women entrepreneurs represent 29% of entrepreneurs in Europe, which means about 11.6 million people. Since 2008 there has been a slight increase of female entrepreneurs in the European Union of around 3%, while in Europe overall women are the overwhelming majority in the one-person business (78%).

According to data provided by the European Commission, women entrepreneurs accounted for 24% of the workforce in Greece while the corresponding percentage for the EU-28 was 10%. The greatest proportions of women entrepreneurs in Greece were in sectors such as education, service activities, human health and social work activities, as well as financial and insurance activities.

Most entrepreneurs in developed or developing countries utilize ICT applications for the development of products, marketing as well as design and strategic objectives. Despite the hampering factors for female entrepreneurship, ICTs could contribute as effective tools for women to have equal opportunities with men in business development (Matthew, 2010).

7 Conclusions

Gender based discrimination in the workplace still exists in our days. Discrimination in relation to the role of women in the global economy, remuneration policy, career development and the patriarchal view that women have the exclusive responsibility for the care of the family. The relevant legislation for gender equality in the workplace is not sufficient to eliminate such discrimination.

Upgrading the role of women in the labor market, either as an employee or as an entrepreneur, as well as the elimination of roadblocks and obsessions are a must for the equal right to employment regardless of gender. At the same time the new conditions formed in the labor market make ICT products and services necessary for any economy and therefore the investment in ICT is the only way for growth.

The rate at which the labor market is evolving nowadays, the creation of new jobs as well as the modernization of the existing jobs, requires continuous employee education and development of ICT-skills in order to become more competitive.

The problem of under-representation of women in the economic critical sectors such as ICTs and in conjunction with policies and EU initiatives to deal with the skills shortage in ICTs, highlights the need to design and implement actions that will activate the female population in the targeted level of training, selection and participation in entrepreneurship and employment with focus on ICTs:

- Actions that promote the participation of women in technology and entrepreneurship and create standards and benchmarks even from secondary education.
- Actions that will enhance the role of women in the field of technology and STEM education (Science, Technology, Engineering and Mathematics), either as an employee or as an entrepreneur.
- Training actions to support the entry of women into the labor market on equal terms regarding working time, remuneration and development.

In order to achieve all the above, the collaboration of all parties involved in the private and public sector is required in order to develop a national strategy based on understanding the requirements of ICTs and the dynamics of women.

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9 References

[1] Arfken, D. E., Bellar, S. L., & Helms, M. M. (2004). The ultimate glass ceiling revisited: The presence of women on corporate boards. *Journal of Business ethics*, *50*(2), 177-186. https://doi.org/10.1023/B:BUSI.0000022125.95758.98

[2] Australia. Workforce Gender Equality Agency (WGEA). (2016). Gender pay gap statistics.

[3] Baumgartner, M. S., & Schneider, D. E. (2010). Perceptions of women in management: A thematic analysis of razing the glass ceiling. *Journal of Career Development*, *37*(2), 559-576. https://doi.org/10.1177/0894845309352242

[4] Bierema, L. L., & Merriam, S. B. (2002). E-mentoring: Using computer mediated communication to enhance the mentoring process. *Innovative Higher Education*, *26*(3), 211-227. https://doi.org/10.1023/A:1017921023103

[5] Booth, A. L., & Van Ours, J. C. (2010). Part-time jobs: What women want?.
[6] Bosch, N., Deelen, A., & Euwals, R. (2010). Is Part-time Employment Here to Stay? Working Hours of Dutch Women over Successive Generations. *Labour*, *24*(1), 35-54. https://doi.org/10.1111/j.1467-9914.2010.00470.x
[7] Bureau of Labor Statistics.(2016). Current population survey annual average data tables.Table 39.www.bls.gov/cps/cpsaat39.htm.
[8] Bygstad, B., &Lanestedt, G. (2009). ICT based service innovation–A challenge for project management. *International Journal of Project Management*, *27*(3), 234-242. https://doi.org/10.1016/j.ijproman.2007.12.002
[9] Cheung, F. M., & Halpern, D. F. (2010). Women at the top: powerful leaders define success as work+ family in a culture of gender. *American Psychologist*, *65*(3), 182. https://doi.org/10.1037/a0017309
[10] Colombo, M. G., Croce, A., & Grilli, L. (2013). ICT services and small businesses' productivity gains: An analysis of the adoption of broadband Internet technology. *Information Economics and Policy*, *25*(3), 171-189. https://doi.org/10.1016/j.infoecopol.2012.11.001
[11] David, H., & Dorn, D. (2013). The growth of low-skill service jobs and the polarization of the US labor market. *TheAmericanEconomicReview*, *103*(5), 1553-1597.
[12] De Vries, L., Gensler, S., & Leeflang, P. S. (2012). Popularity of brand posts on brand fan pages: An investigation of the effects of social media marketing. *Journal of InteractiveMarketing*, *26*(2), 83-91. https://doi.org/10.1016/j.intmar.2012.01.003
[13] Doucek, P. (2011). Human capital in ICT–competitiveness and innovation potential in ICT. *IDIMT*, 11-22.
[14] Eagly, A. H., & Karau, S. J. (2002).Role congruity theory of prejudice toward female leaders. *Psychological review*, *109*(3), 573. https://doi.org/10.1037/0033-295X.109.3.573
[15] Erdoğmuş, İ. E., &Cicek, M. (2012).The impact of social media marketing on brand loyalty. *Procedia-Social and Behavioral Sciences*, *58*, 1353-1360. https://doi.org/10.1016/j.sbspro.2012.09.1119
[16] Estrin, S., & Mickiewicz, T. (2011).Institutions and female entrepreneurship. *Small business economics*, *37*(4), 397-415. https://doi.org/10.1007/s11187-011-9373-0
[17] European Commission (2011). Europe 2020: Flagship Initiative Innovation Union
[18] European Commission. (2014). Statistical Data on Women Entrepreneurs in Europe
[19] Felstead, A., Gillie, D., & Zhou, Y. (2007) Skills at Work, 1986-2006, ESRC Centre on Skills, Knowledge and Organisational Performance (SCOPE).
[20] Garrido, M., Sullivan, J., & Gordon, A. (2010, December).Understanding the links between ICT skills training and employability: an analytical framework. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development* (p. 15).ACM.
[21] Gourova, E., Antonova, A., &Nikolov, R. (2006).Building skills for the knowledge society. In *Third International scientific conference Computer Science, Istanbul, 12-15 October 2006* (pp. 107-112).
[22] Gilster, P., & Glister, P. (1997). *Digital literacy*. New York: Wiley Computer Pub..
[23] Green, F., Felstead, A., Gillie, D., & Zhou, Y. (2007, July). Computers and pay. National Institute Economic Review, 201(1), 63–75. https://doi.org/10.1177/0027950107083051
[24] Hanna, N. K. (2010). ICT Services Industry for an Innovation Economy. In *Enabling Enterprise Transformation* (pp. 135-158). Springer New York. https://doi.org/10.1007/978-1-4419-1508-5_6
[25] Headlam-Wells, J. (2004). E-mentoring for aspiring women managers. *Women in Management Review*, *19*(4), 212-218. https://doi.org/10.1108/09649420410541281

[26] Headlam-Wells, J., Gosland, J., & Craig, J. (2006). Beyond the organization: The design and management of E-mentoring systems. *International Journal of Information Management*, *26*(5), 372-385. https://doi.org/10.1016/j.ijinfomgt.2006.04.001
[27] Hollenstein, H. (2004). Determinants of the adoption of Information and Communication Technologies (ICT): An empirical analysis based on firm-level data for the Swiss business sector. *Structural change and economic dynamics*, *15*(3), 315-342. https://doi.org/10.1016/j.strueco.2004.01.003
[28] Jackson, J. F., & O'Callaghan, E. M. (2009). What do we know about glass ceiling effects? A taxonomy and critical review to inform higher education research. *Research in Higher Education*, *50*(5), 460-482. https://doi.org/10.1007/s11162-009-9128-9
[29] Kobeissi, N. (2010). Gender factors and female entrepreneurship: International evidence and policy implications. *Journal of International Entrepreneurship*, *8*(1), 1-35. https://doi.org/10.1007/s10843-010-0045-y
[30] Laurijssen, I., & Glorieux, I. (2013). Career trajectories for women after childbirth: Job quality and work–family balance. *European sociological review*, *29*(3), 426-436. https://doi.org/10.1093/esr/jcr082
[31] Lim, S., & Cortina, L. M. (2005). Interpersonal mistreatment in the workplace: the interface and impact of general incivility and sexual harassment. *Journal of applied psychology*, *90*(3), 483. https://doi.org/10.1037/0021-9010.90.3.483
[32] Mandel, H., & Shalev, M. (2009). How welfare states shape the gender pay gap: a theoretical and comparative analysis. *Social Forces*, *87*(4), 1873-1911. https://doi.org/10.1353/sof.0.0187
[33] Mathew, V. (2010). Women entrepreneurship in Middle East: Understanding barriers and use of ICT for entrepreneurship development. *International Entrepreneurship and Management Journal*, *6*(2), 163-181. https://doi.org/10.1007/s11365-010-0144-1
[34] Minniti, M., &Naudé, W. (2010). What do we know about the patterns and determinants of female entrepreneurship across countries?. *The European Journal of Development Research*, *22*(3), 277-293. https://doi.org/10.1057/ejdr.2010.17
[35] Nayyar, P., Sharma, A., Kishtwaria, J., Rana, A., & Vyas, N. (2007). Causes and constraints faced by women entrepreneurs in entrepreneurial process. *The Journal of Social Science*, *14*(2), 99-102.
[36] Roberts, B. S., & Mann, R. A. (1995). Sexual harassment in the workplace: A primer. *Akron L. Rev.*, *29*, 269.
[37] Roztocki, N., &Weistroffer, H. R. (2009). Research trends in information and communications technology in developing, emerging and transition economies. *Collegium of Economic Analysis*, *20*, 113-127.
[38] Tackling the gender pay gap in the European Union
[39] Terrell, K., &Troilo, M. (2010).Values and female entrepreneurship. *International Journal of Gender and Entrepreneurship*, *2*(3), 260-286. https://doi.org/10.1108/17566261011079242
[40] Turlea, G., Nepelski, D., De Prato, G., Lindmark, S., de Panizza, A., Picci, L., ...&Broster, D. (2010). The 2010 report on R&D in ICT in the European Union. *JRC Scientific and Technical Report, JRC-IPTS. Available at: http://ipts. jrc. ec.europa. eu/publications/pub. cfm*.
[41] Underwood, J., & Khosrowshahi, F. (2012).ICT expenditure and trends in the UK construction industry in facing the challenges of the global economic crisis. *Journal of Information Technology in Construction*, *17*, 26-41.
[42] Vanderpool, C., & Way, S. A. (2013).Investigating work–family balance, job anxiety, and turnover intentions as predictors of health care and senior services customer-contact em-

ployee voluntary turnover. *Cornell Hospitality Quarterly*, *54*(2), 149-160. https://doi.org/10.1177/1938965513478682

[43] Várallyai, L., &Herdon, M. (2010).E-SKILLS EFFECTS TO LABOUR MARKET. *The Economies of Balkan and Eastern Europe Countries in the changed world*, 21.

[44] Violence against women: an EU-wide survey Main results, (2014). European Union Agency for Fundamental Rights.

[45] Willness, C. R., Steel, P., &Lee, K. (2007).A meta-analysis of the antecedents and consequences of workplace sexual harassment. *Personnel Psychology*, *60*(1), 127-162. https://doi.org/10.1111/j.1744-6570.2007.00067.x

[46] Wintjes, R. E. N. É., &Dunnewijk, T. H. E. O. (2008). Sectoral innovation systems in Europe: The case of the ICT sector. *Europe-Innova*, *9*.

10 Authors

Marios Pappas (B.Sc., M.Ed.) is a research associate at N.C.S.R. Demokritos, Institute of Informatics and Telecommunications, Net Media Lab, Athens, Greece (e-mail: mpap@iit.demokritos.gr).

Yannis Papagerasimou (B.Sc., M.Sc.) holds a Bachelor degree in Electronic and Computer Engineering and a Master's degree in Data Communications. He is a research associate at N.C.S.R. Demokritos, Institute of Informatics and Telecommunications, Net Media Lab, Athens, Greece (e-mail: ypapa@iit.demokritos.gr).

Athanasios Drigas is a Director of Research at IIT - N.C.S.R. Demokritos. He is the Coordinator of Telecoms Lab and founder of Net Media Lab since 1996. From 1990 to 1999 he was the Operational manager of the Greek Academic network. He has been the Coordinator of Several International Projects, in the fields of ICTs, and e-services (e-learning, e-psychology, e-government, e-inclusion, e-culture etc). He has published more than 280 articles, 7 books, 25 educational CD-ROMs and several patents. He has been a member of several International committees for the design and coordination of Network and ICT activities and of international conferences and journals. (e-mail: dr@iit.demokritos.gr).

Dimitris Raftopoulos (B.Sc., M.Sc.) is a research associate at N.C.S.R. Demokritos, Institute of Informatics and Telecommunications, Net Media Lab, Athens, Greece (e-mail: dimitris@ecwt.eu).

Pantelis Nikolaidis (B.Sc., M.Sc.) is a research associate at N.C.S.R. Demokritos, Institute of Informatics and Telecommunications, Net Media Lab, Athens, Greece (e-mail: pnikolai@otenet.gr).

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Teacher-Researchers as Levers of Doctoral Curriculum in Engineering

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Pia Lappalainen
Aalto University, Language Centre
Leipzig University, Language Centre
pia.lappalainen@aalto.fi

Abstract—Policy-level interventions aim to expedite institutional change in universities but the related decisions rarely materialize as sustained grassroots-level implementations genuinely transforming teaching or learning practices. As a solution, educational authorities have called for scientific evidence as base for university reforms. This article showcases an empirical development endeavor from Aalto University that, while responding to doctoral students' learning needs and institutional demands for higher publication productivity, paves the way for a more extensive bottom-up institutional reform of doctoral education. The data-driven analysis of a sample of 381 doctoral candidates in engineering directs the pedagogic focus in a doctoral writing course away from grammar and language proficiency towards writing support that accentuates usability and communicative value. The primary aim is to conceptualize a writing intervention that is based on authentic researcher needs. The secondary aim is to substantiate allocation of language teachers' working hours to research by demonstrating how audience needs analyses can benefit teacher renewal, the quality of education, and institutional performance as measured through key institutional metrics.

Keywords—doctoral education, language studies, publication productivity, student needs analysis

1 Introduction

In the competitive education economy, European universities are preoccupied with efforts to climb up the international ranking ladders to secure their reputation, to attract the most potent student material [1], to collect the largest possible share of state funding, and in the long run, to survive the global battle [2].

One of the fiercest rivalries materializes in the arena of doctoral education, in which productivity constitutes the traditional measure of institutional and individual performance. The expanding authorship community has produced a burgeoning number of publications, which compete for the citations of the simultaneously enlarging readership [3]. Citation counts and the related bibliometrics have been adopted to gauge the global reach and disciplinary status of university-hosted research [4] when

substantiating tenure and funding decisions [5]. Productivity measures drive university performance also externally; as public funding is strongly dependent on performance indicators, universities are desperately seeking interventions increasing accountability by expediting doctoral degree completion and promoting a higher quality of candidate outputs [6], [7].

Even though the prevalent university improvement measures are, no doubt, well intended, they represent policy-level actions inspired by institutional pressure and are too rarely founded on research data on actual student needs or knowledge gaps. Politically motivated action typically pursues change for change's sake, seeking immediate gains at the cost of a more profound and sustainable reform [8]; [9] potentially even jeopardizing the university culture [10].

Subsequent calls for a university education reform, reconceptualization, re-envisioning, reframing, rethinking, harmonizing or formalizing are being voiced on European, national and university levels to address both the entrenched problems as well as some more recently articulated ones [11]. The former include such measurable outcomes as low and long completion times and graduates' poor match with industrial employment criteria, that is soft, intercultural [12], emotional, and social skills [13]. In contrast, the latter, more recently emerging issues center on higher-level goals, including the ability to tackle societal, social, economic, political, market and environmental challenges [14], [15].

Given the ramifications of publishing activity for the survival of individual universities, the small number of investments made in researchers' writing education comes as a surprise. Studies have shown that researchers universally need support in academic writing for publication [16] with their supervision typically being directed narrowly to the subject area and methodology.

As an effort to remedy this problem of practice, this article documents a grassroots-level teacher-initiated analysis of students needs to show how syllabi can be re-examined and iteratively enhanced with reasonable efforts, adopting design-based research. The study subsequently offers two contributions to engineering pedagogy. First, it conceptualizes an intervention based on doctoral candidates' authentic learning needs. Second, it promotes a sustained and targeted bottom-up reform by appealing to Language Centre policy-makers to root a system allowing research investments in language teachers' annual contracts.

2 Towards bottom-up university reform

Such higher-level policy ideals instigated on the EU level as the Bologna Process aim to systematize higher education and accreditation criteria on the European level [17]. However, they may ignore the day-to-day realities of doctoral supervision as well as the requirements for supervisory care and ethics in the collaboration between the supervisor and the supervisee [18], which is known to affect the success of doctoral education [19].

Indeed, reports on successful university improvement endeavors have shown that internally generated changes typically yield the most positive impact compared to

political imperatives. Naturally, traditional and taken-for-granted pedagogical practices offer value through automated, familiar routines [20] but have not proven effective in actualizing a positive change in degree attainment or in increasing the number of publications produced.

Another challenge induced by a change imposed top down is that it often envisions a desired goal but could fail to detail implementation. Without accurate diagnosis of the flaws, it is difficult to devise an improvement plan that allows transforming the change agenda from rhetoric attempts at renewal to a sustained reality. A vision without execution remains mere rhetoric or could even disrupt the persistent long-term development that committed teachers pursue as their more subtle and routine mode of operation [21].

A third hurdle in university development stems from contextuality, which hurdles effective replicability [22]. The local, institutional, professional, and classroom cultures and social make-up drive educational outcomes, questioning the benefits from replicating best practices from other countries, institutions or pedagogues [23]. Especially in doctoral education, borrowing previous reform strategies is an unfeasible option as systematic programs have only recently been set up, with little documented evidence of their success available thus far.

When genuinely pursuing change implementation, it is essential to keep in mind that despite the ostensible focus on the system level, the execution takes place in the classroom, through the teaching and learning processes. In the classroom, it is the teacher and his or her practices that contribute to student achievement; pedagogical leaders mediate learning outcomes by enacting an educational climate that either promotes or inhibits learning. The pedagogue's critical role in eliciting results among learners evokes performance beyond that explained by tangible resources [24], [25]. Profound instructional development therefore requires an internally motivated cultural change, which cannot be mandated. To authentically be able to act differently, teachers need self-renewal through capacity building that enhances their motivation, increments competences and secures resources [26].

Teacher capacity in doctoral programs refers centrally to the intellectual capital of the pedagogue [27], materializing as analytical and effective pedagogy. The focus in teaching activities, however, ought to be directed to service, which is in deliberate contrast to earlier approaches to doctoral education as top-down supervision. Service-orientation also attends to the recent international shift toward the social nature of the supervisor-researcher relationship [28].

Supervision as service constitutes the centerpiece of the present study, which aims to expand understanding of the under-researched dimension of higher education that examines students as consumers [29], [30]. Traditionally, responsiveness to student needs has been pursued through supply-driven education based on pedagogues' prior understanding of student needs and the extensive insight into pedagogic development nationally cumulated in Finland. The Finnish teacher education system is globally recognized for its high quality, with teachers standing in high international esteem for their pedagogic expertise and top-notch PISA results [31]. Unfortunately, the Finnish pedagogical training essentially prepares teachers for the first two tiers in the education system, offering few instruments for the third, post-graduate level.

The present calls to advance research on service-minded education pedagogy, particularly its breadth and diversity, as well as the personal relationships involved, strive to horizontalize the pedagogical space and the entire conception of doctoral education [32]. As a new conceptual dimension, students as consumers requires more targeted utility, high quality, factors ensuring personal interest, and individualized and unique study plans securing retention and study progress [33]. Doctoral candidates also expect practical relevance of their studies, preferably through integration of industrial operators into doctoral education [34], [35].

Unfortunately, the traditional language teacher role in Europe has not allowed research as part of the annual work contract, which would be instrumental also for teachers' occupational development and self-growth and professional renewal. The design-based research orientation is proposed here as a way of expanding the role of the language teacher into teacher-researcher. Further, this article examines systems-level institutional change through an individual teacher's research efforts and describes a development initiative from Aalto University that is based on student needs. The results demonstrate that doctoral candidates require support not only in their core research activities, but also in tackling the various mental barriers and inhibitions related to documenting one's research. This study was motivated by calls to meet doctoral student needs more holistically and in a more targeted fashion but additionally ended up addressing the central tenets of teacher position in the university system. Ultimately, it aimed to enhance the quality of doctoral education and promote system-level change at Aalto University.

3 Designing demand-driven doctoral education

Following the basic-degree studies that are well formalized, structured and instructed, the ambiguous nature of doctoral studies easily discourages doctoral candidates, as does also the fierce competition. Scholarly publishing is depicted as communicative practice, with two competing aims: on the one hand, researchers are striving to have their products read and acknowledged by an audience as wide as possible; on the other hand, they must accommodate to the conventions of their own community in order to pass peer reviews [36].

These circumstances call for particular pedagogic approaches and modes of instruction. To design a doctoral course assisting doctoral candidates in the competitive, global research community, an investigation of doctoral candidates' needs was initiated by one of the English lecturers. The aim was to make student voices better heard and to consider their learning gaps more holistically in the curriculum design process. At the same time, the endeavor aimed to respond to the University management calls for faster doctoral degree completion and higher dissertation quality.

3.1 Design-based research as the study method

To build a pedagogically and scientifically informed education offering that meets student needs, the present study adopted a method following the principles of design-

based research, as outlined in Figure 1. The method is well-established in learning sciences and serves both pragmatic and theoretical aims. It allows interventionist syllabus design that promotes a new type of a learning environment. The method enables an in-depth understanding of the learning process, as well as expansion of the teacher role into teacher-researchers [37].

The design-based research approach was adopted in the present examination to monitor doctoral candidates' perceptions in 2011-2016 through four, complementary rounds of analyses to identify topics, content and emphases for the new the Writing Doctoral Research course that was being set up for post-graduate students at the University Language Centre. Design-based research blends empirical educational research with the theory-driven design of learning environments and allows iterative, continuous cycles of implementation that move from design to enactment, analysis and redesign of pedagogical innovations. As outcomes, the method yields sharable theories that explain how the resultant designs function in authentic settings [38].

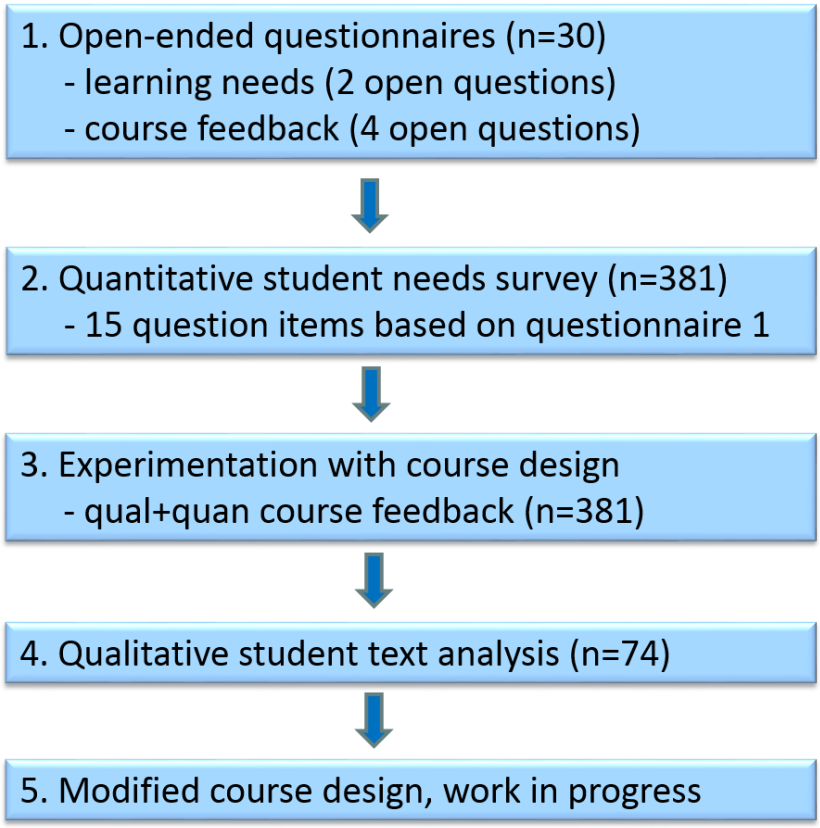

Fig. 1. Process of data collection.

The first survey revealed some problems that could not be addressed by the Language Centre: too few lab facilities, poor lab maintenance, lack of professor-level supervision, missing support with methodological choices, and lacking or too short-term funding instruments, which forces candidates to constantly engage in grant application. These messages were delivered to the University-level doctoral program management for further processing.

Leaving aside topics outside the Language Centre's authority, three main categories surfaced from the responses that dominated student perceptions in the two first-stage questionnaires: content creation, production of text, and feedback reception. This is in alignment with prior literature indicating that writing for publication involves investment in content, process and critique [39]. Content refers to the ability to argue on the grounds of literature or empirical evidence. Process acknowledges scholarly writing as an iterative effort of rewriting. Finally, critique comprises skills in feedback reception and provision during the drafting and rewriting phases.

In the second phase, the three topic areas raised in the first two questionnaires were further divided into 15 sub-dimensions for a quantitative survey according to the key words in the student responses. They were organized into a survey using a Likert scale from 1 (not very important) to 5 (very important). Following the principles of design-based research and its cycle-based iterative development, every Writing Doctoral Research course begins with this survey, providing the teacher with valuable background information regarding the student audience. The accumulated responses presently comprise 381 respondents.

The qualitative analysis of 74 student abstracts or introductions was an important complementary method to acquire a more objective view of competence gaps, in addition to the subjective student views collected quantitatively. The analysis confirmed the results from the quantitative survey, corroborating that the utility of research writing education at Aalto needs to be enhanced and quality of publications improved with accentuated support for certain components in the writing process. The scrutiny revealed the need to specialize in engineering conventions specifically in quantitative methodology, and to direct attention to engineering socialization, theoretical profiling and enculturation [40] to accommodate to journal requirements. The analysis also revealed dimensions that students were unaware of: textual redundancy, inability to articulate thesis aims, ambiguous use of tenses and voices in data commentary, lack of hedging strategies, and overuse of passive constructions.

3.2 Results – priorities for course design

The scores received from the sample of 381 doctoral candidates were analysed for averages, medians and standard deviations to identify priorities for further course design (Table 1). The averages show that issues related to feedback were found to be of minor challenge among the 15 components but the mere fact that they were raised in student responses naturally calls attention to the emotive processes involved in critique.

Table 1. Results from the quantitative survey (n=381).

	Question item	Avrg	St dev	Median
1	**Detecting my own mistakes**	3.76	1.03	3
2	**Polishing my style**	3.69	0.89	3
3	**Expressing my views with precision**	3.63	0.90	3
4	**Mastering grammar**	3.38	1.03	3
5	**Getting started with writing**	3.36	0.92	3
6	**Arguing for my ideas**	3.32	0.89	4
7	**Organizing sentences**	3.27	0.89	4
8	**Deciding what to implement**	3.27	0.99	3
9	**Organizing ideas**	3.24	0.91	3
10	**Finding appropriate terminology**	3.23	0.98	3
11	**Finding credible sources**	3.04	0.80	4
12	**Generating ideas**	2.83	0.84	3
13	**Understanding counter-arguments**	2.73	0.98	2
14	**Not getting too emotional**	2.73	1.05	3
15	**Accepting constructive criticism**	2.52	0.85	3

In the entire listing, two items, *Getting started with writing* and *Not getting too emotional* when receiving feedback yielded an above-average standard deviation, 1.01 and 1.06, respectively, indicating that some students deviated strongly from the general trend with their opposing perceptions. Three items received upper-scale medians: *Detecting my own mistakes*, *Polishing my style* and *Expressing my views with precision,* meaning that they were by half of the respondents scored as 5 in the survey, corroborating the score averages and signaling the urgency of these learning foci. The element averaging highest, *Detecting my own mistakes*, coincides with today's pedagogic trend towards reflective practice [41], encouraging the implementation of strategies that help students to help themselves.

The importance of *Academic style*, ranking second in the present survey, is confirmed by also other studies showing that the author's specific stylistic and organizational choices matter greatly as they support overall text usability but also the build-up of author credibility and content reliability by steering reader perceptions [42]. Style is probably the most evident feature of academic writing: it materializes in many aspects and levels of writing and visibly manifests the register or genre of the text. Fortunately, as style mostly materializes in micro-level language usage, it is also easy and quick to improve. However, the composition of text not only involves micro-level

mechanics of writing but also deeper, macro-level strategies supporting argumentation and positioning and enhancing persuasion and credibility aims [43].

Both the quantitative and qualitative studies revealed handicaps in author ability to make solid arguments instead of conveying insights or intuitive opinions. In the present survey, student concerns over preciseness convey an academic awareness and stance, as precision and accuracy constitute important features of academic writing, especially in terms of argumentation. Precision and clarity of expression are particularly essential when critically reporting one's own empirical results but also when objectively reviewing other authors' studies while providing sufficient credit [44], [45].

Alarmingly, the top-5 list includes a mental component, *Getting started with writing*, which draws attention to the socio-emotive load involved in the writing process. Students' writing strategies obviously require more attention but due to time constraints in a course as short as 36 hours, and also due to teacher unpreparedness for such a demanding topic, the writer's block is addressed only superficially in small group discussions and teacher feedback sessions and some general guidelines are sketched for drafting a new text. However, the teacher is adamant about future inclusion of such mental processes.

Grammar being raised as a challenge was somewhat surprising, as the English proficiency level is extremely high among doctoral candidates. This result can perhaps be explained by the European education system, in which language teaching has traditionally placed much emphasis on grammar and correctness. As a result, students are proficient but also excessively cautious about making mistakes. Correct grammar is naturally a concern in academic writing that aims at publication but respondent biases stemming from educational emphases may have influenced the scores received for this question item. Also social desirability and the pressure students sense from the environment may encourage them to emphasize grammar in a survey that was organized by a Language Centre. The author is therefore inclined to attribute some of this concern rather to the education culture than any severe handicaps in the area.

An analysis of the received data for score averages, medians and standard deviations yielded a priority of course topics, with the averages indicated in Figure 2.

Due to the small sample size (n=381) and rather unscientific labeling of the question items based on the preliminary student responses, these results have to be regarded as suggestive. However, they provide indication of the average needs of the majority and thereby suggest emphases for the course design.

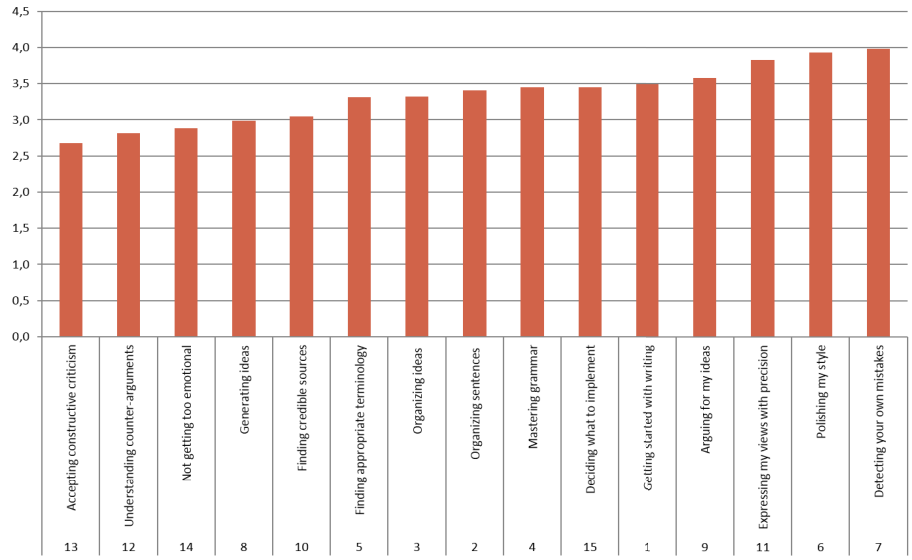

Fig. 2. Thematic priorities based on the quantitative survey.

3.3 Subsequent course principles

Based on the data analyzed for the purposes of the present doctoral course design, the development endeavor described in this article deviated from bachelor's and master's-level foci on language proficiency in other language courses at the University. To build on the knowledge acquired during basic degree studies and to elevate the level of difficulty of the learning content, this course centers on communicative aspects. The key pedagogic principle, usability, was adopted from the international ISO standard, which defines usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [46]. This aligns effectively with the aims of a course that promotes successful journal review outcomes, with publications being the *products*.

Effectiveness in the related course refers to message accuracy and unambiguousness, methodological validity, data reliability and scientific data commentary conventions that provide due credit to original authors and leave the tone unaltered from the initial reporting. Efficiency was translated to this context as conciseness and lack of redundancy. Typically it also involves avoidance of nominalization and phrasal verbs, and a shift in voice from passive to active, which harnesses subject-verb connection and subsequent text intelligibility and flow, reducing reader effort. Finally, user satisfaction here means readability and the subjective user experience, which can be promoted through appropriate terminology, academic style, coherence and logical topicalization.

In addition to a strong focus on usability topics, the course was founded on two pedagogic principles. First, all materials and exercises were authentic engineering

samples in a language bath style, to accustom the students to engineering conventions, jargon and idioms in a fashion as holistic and effective as possible. Second, the course put effort to ridding students of writing inhibitions by repeatedly highlighting two guidelines: 1) one learns to write by writing, and 2) quality comes from revision. These guidelines were enforced through continuous, constructive feedback, which departed from acknowledgement that the first draft is by default incomplete but will eventually grow into full-fledged academic output through iterative revising and peer input.

3.4 Course design

The 3 ECTS Writing Doctoral Research course follows the standard 36-hour frame of the University, with 9 sessions organized into 4-hour blocks (Figure 3). The sessions were organized and built on the foundation of the survey results as follows:

1. As the survey indicated already with smaller samples, detecting one's own mistakes (1st) poses challenges to any writer, which is why a peer review was added early on to the end of every session. By monitoring mistakes in a peer's paper, researchers learn to detect errors in their own manuscripts. In addition, 4 of the sessions were dedicated entirely to teacher/peer feedback for more detailed scrutiny.
2. As style emerged as the most critical topic (2nd), an entire session was dedicated to stylistic features in academic writing for publication.
3. Precision of claims and accuracy of arguments ranked 3rd and 6th, respectively, indicating that reporting posed problems for the doctoral candidates in the sample. A session was therefore designed to cover data commentary and reporting conventions, which provide most incidents and a logical ground for claim statements and arguments.
4. Organization of sentences and ideas were identified as difficult (7th and 9th, respectively), which revealed the need to focus on coherence, redundancy, readability and flow, that is, aspects impacting reader satisfaction.
5. Grammar (4th) was subtly integrated to all sessions and teacher reviews as an inherent component in a language course.
6. Such mental issues as writing inhibitions (5th) as well as processes involved in feedback (emotionality 14th and acceptance of criticism 15th) were focused on in the last, wrap-up sessions in a targeted fashion but naturally also whenever emotional challenges were addressed by students in class.
7. Additionally, the qualitative analysis revealed that engineers lacked patterns and strategies establishing the relevance of their topic, as well as rhetorical elements supporting their positioning. These themes comprised the course opening and allowed the doctoral candidates to delve into their Introductions and Abstracts.

Overall, the course skeleton could be depicted as illustrated in Figure 3.

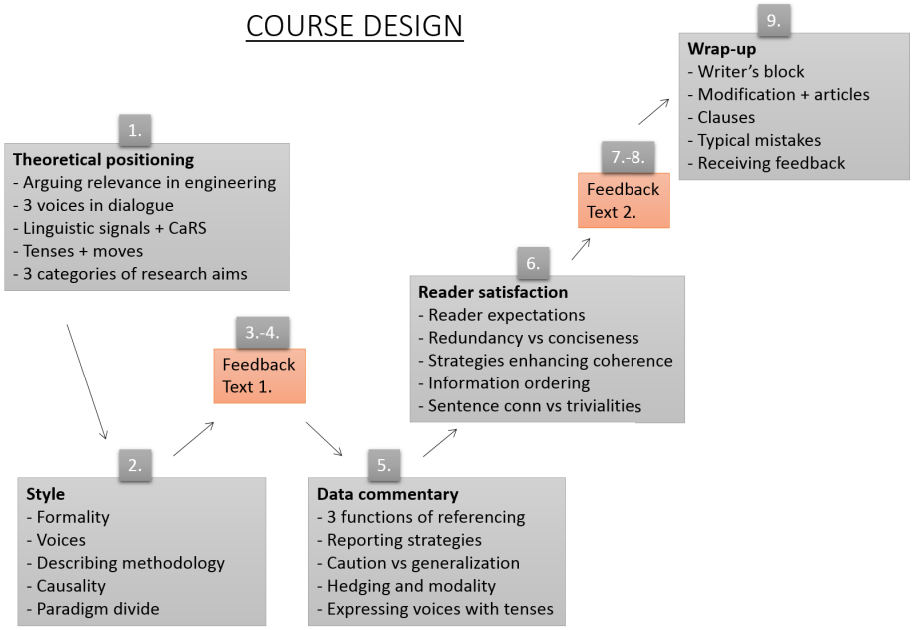

Fig. 3. Writing Doctoral Research course organization.

Four of the sessions are dedicated to half-group teacher/peer-reviews so that each candidate receives feedback that is prepared beforehand on his/her manuscript twice during the course. In addition, each lecture ends in a 30-minute peer review, in which students monitor each other's products against a checklist that reviews the topics covered in the session in question. This serves as means of responding to student calls for more mentoring, mental support and face-to-face supervision. It is also a solution to the number 1 problem raised in the analysis: detecting mistakes in their own writing.

It is important to note that even after 6 years, the course is still work in progress. In alignment with the principles of design-based research, the course evolves continually through iteration based on new student groups' needs and feedback. Continuous development is naturally a necessity also as the doctoral candidates' manuscripts focus on technology topics; to secure authenticity, relevance and up-datedness, the examples and exercises must keep up with real-life trends and technological development.

4 New policy call

University units typically demonstrate their qualification through research orientation, with staff excellence being measured by publication productivity. Fortunately, the shift in focus towards didactic and pedagogical competences [47] is directing attention to teachership that positively impacts learning outcomes. Such verbal and

nonverbal behaviors that lead to student empowerment, motivation and perception of connectedness stem from teacher's service-mindedness and positively alter the student-teacher relationship [48], supporting post-graduate study progress and expediting degree completion [49].

A fundamental change of this magnitude in teaching practices is urged by calls to move from processual transmission of substantive knowledge to a more holistic build-up of professional expertise and reflective practice in engineering education [50]. Teachers are expected not only to master their subject matter but also to know their learners and learner needs [51]. This is fundamental when designing targeted curricula for the doctoral level [52].

Securing teachers' professional development serves as a key strategy in educational reform [53]. Improvement towards pedagogic excellence requires distributed leadership, redistribution of power to teachers and continuous learning. In the absence of training and formal education, teachers need to take responsibility for their self-development but this poses expectations for teacher authority and autonomy, not only as teachers but also as researchers. Pedagogical leadership and the related capacity build-up necessitates democracy and independence, but also initiative, energy, commitment and responsibility – not to mention funding in terms of hours allocated to research [54].

This investigation aims to advance doctoral candidates' benefits by shifting educational reform foci to teacher-researchers, even and especially in the case of language teachers. This has persistently been challenged by policy-level decisions that as language studies represent the non-core, they do not have to be based on empirical research. These arguments overlook the potential in integrated teaching, which intensifies multidisciplinary learning [55].

However, several arguments promote such a reform. First of all, students have the right to expect research-based teaching in all sectors of their degree studies. Second, teacher motivation can easily be elevated by securing the relevance of the education supply through authentic student demands. Third, teachers' competences grow when they are allowed to research and learn more about topics of relevance and of authenticity. Finally, teacher resources can best be secured through research evidence that substantiates the (re-)allocation of scarce university resources in the classroom. However, such institutional and teacher renewal requires efforts from teacher-researchers [56] that must be compensated for.

5 Conclusion

The increasingly competitive research economy has pushed universities to re-examine their doctoral offerings. Efforts abound but they have often been accused of being divorced from the problems of everyday practice. To bridge the gap between theoretically oriented institutional policies and classroom practice, this study set out conceptualize an intervention that would draw on authentic post-graduate needs. To design syllabi for the doctoral level that would fill both individual researchers' requirements and those of their host university, this study examined needs and factors

impacting publication productivity. Scholarly writing was earlier dismissed as a mere cosmetic component of little importance in the overall thesis process, compared to the scientific and empirical investigation. It has also been regarded as a skill that could be taught separate from content and context [57]. This, however, underestimates the complexity of thesis writing, in which the field-specific conventions, unique discourses and research traditions dictate and characterize the writing style and structure.

A particular challenge with doctoral education stems from the pressure to address both the quality and the quantity of doctoral outputs. Students often regard these as competing aims, but contrastively, this study implies that investment in one, quality, bolsters the other, quantity, as facilitation of academic writing strategies tends both to lift the quality of writing and to speed up the writing process. Overall, the analysis reported in this article not only points out emphases for a doctoral writing course but also signals that thesis completion depends strongly on university-provided support for the writing process, directed to such dimensions of text usability as efficiency, effect and reader satisfaction, as well as the authors' mental processes.

When aligning with the recent trends for demand-driven education and service orientation, the performability of research support can no longer be measured only in terms of such calculable terms as publication productivity and degree attainment time. Instead, or rather additionally, focus ought to be directed to quality: the motivational aspects embedded in the supervision process, including inspiration and emotive support as well as the level of specificity and contextualization of teaching content deserve more attention.

Such a new stance to investment in and monitoring of research outputs requires capacity building, not only of teachership but also of the entire university arena. This is the only way towards a broader scope of education, a more productive researcher base – and a more sustained transformation of the university institution into a high-performing service unit. However, it is important to acknowledge that ultimately the transformation takes place in the classroom and is led by teacher-researchers, for whom analysis of student needs should be made business as usual among their constant efforts to improve educational practices.

6 References

[1] G. Bossa, "Europe's Universities in Response to Europe's Challenges". *Higher Education in Europe*, 2006, Vol. 31(4), pp. 355-357. https://doi.org/10.1080/03797720701302907

[2] A. Harris, "Leading system-wide improvement". *International Journal of Leadership in Education: Theory and Practice*, 2012, Vol. 15(3), pp. 395-401. https://doi.org/10.1080/13603124.2012.661879

[3] S. Nawaz and J. Strobel, J. "Authorship and Content Analysis of Engineering Education Research. A Case Study". *International Journal of Engineering Pedagogy*, 2016, Vol. 6(2), pp. 39-51. https://doi.org/10.3991/ijep.v6i2.5577

[4] B.Williams, P. Neto, and P. Wankat, "Taking a Snapshot: Four Bibliometric Indicators To Track Engineering Education Research Evolution". *International Journal of Engineering Pedagogy*, 2014, Vol. 4(4), pp. 16-22. https://doi.org/10.3991/ijep.v4i4.3843

[5] K. Bauer and N. Bakkalbasi, "An Examination of Citation Counts in a New Scholarly Communication Environment". *D-Lib Magazine*, 2005, Vol. 9(11), http://www.dlib.org/dlib/september05/bauer/09bauer.html. https://doi.org/10.1045/september2005-bauer

[6] C. Halse and J. Malfroy, "Retheorizing doctoral supervision as professional work". *Studies in Higher Education*, 2010, Vol. 35(1), pp. 79-92. https://doi.org/10.1080/03075070902906798

[7] C. Aitchison and A. Lee, "Research writing: problems and pedagogies". *Teaching in Higher Education*, 2006, Vol. 11(3), pp. 265-278. https://doi.org/10.1080/13562510600680574

[8] A. Harris, "Leading system-wide improvement". *International Journal of Leadership in Education: Theory and Practice*, 2012, Vol. 15(3), pp. 395-401. https://doi.org/10.1080/13603124.2012.661879

[9] L. McAlpine and C. Amundsen, "Challenging the taken-for-granted: how research analysis might inform pedagogical practices and institutional policies related to doctoral education". *Studies in Higher Education*, 2012, Vol. 37(6), pp. 683-694. https://doi.org/10.1080/03075079.2010.537747

[10] C. Bruce and I. Stoodley, "Experiencing higher degree research supervision as teaching". *Studies in Higher Education*, 2013, Vol. 38(2), pp. 226–241. https://doi.org/10.1080/03075079.2011.576338

[11] J. Cumming, "Doctoral enterprise: a holistic conception of evolving practices and arrangements". *Studies in Higher Education*, 2010, Vol. 35(1), pp. 25-39. https://doi.org/10.1080/03075070902825899

[12] M. Ehses and M. Veith, "The International Research Training Group (GRK532): Practicing Cross-border Postgraduate Education". *Higher Education in Europe*, 2009, Vol. 3-4, pp. 367-384. https://doi.org/10.1080/03797720903355620

[13] U. Oberst, et al. "Training Emotional and Social Competences in Higher Education", Higher Education in Europe, 2009, Vol. 34(3-4), pp. 523-533. https://doi.org/10.1080/03797720903392243

[14] C. Halse and J. Malfroy, "Retheorizing doctoral supervision as professional work". *Studies in Higher Education*, 2010, Vol. 35(1), pp. 79-92. https://doi.org/10.1080/03075070902906798

[15] L. Suarez and W. Hernandez, "Leadership and performance in higher education: a comparative analysis in Portugal and Spain". *European Journal of Engineering Education*, 2012, Vol. 37(6), pp. 592–599. https://doi.org/10.1080/03043797.2012.729810

[16] B. Crossouard, "Conceptualising doctoral researcher training through Bernstein's theoretical frameworks". *International Journal for Researcher Development*, 2013, Vol. 4(2), 72-85. https://doi.org/10.1108/IJRD-05-2013-0007

[17] T. Saarinen and T. Ala-Vähälä. "Accreditation, the Bologna Process and National Reactions: Accreditation as Concept and Action". *Higher Education in Europe*, 2007, 32(4), 333-345. https://doi.org/10.1080/03797720802066195

[18] C. Halse and J. Malfroy, "Retheorizing doctoral supervision as professional work". *Studies in Higher Education*, 2010, Vol. 35(1), pp. 79-92. https://doi.org/10.1080/03075070902906798

[19] A. Franke and B. Arvidsson, "Research supervisors' different ways of experiencing supervision of doctoral students. *Studies in Higher Education*, 2011, Vol. 36(1), pp. 7–19. https://doi.org/10.1080/03075070903402151

[20] L. McAlpine, C. Amundsen, "Challenging the taken-for-granted: how research analysis might inform pedagogical practices and institutional policies related to doctoral educa-

tion". *Studies in Higher Education*, 2012, Vol. 37(6), pp. 683-694. https://doi.org/10.1080/03075079.2010.537747

[21] A. Harris, "Leading system-wide improvement". *International Journal of Leadership in Education: Theory and Practice*, 2012, Vol. 15(3), pp. 395-401. https://doi.org/10.1080/13603124.2012.661879

[22] D. Malouf and J. Taymans, "Anatomy of an Evidence Base". *Educational Researcher*, 2016, Vol. 45(8), pp. 454-459. https://doi.org/10.3102/0013189X16678417

[23] A. Harris, "Leading system-wide improvement". *International Journal of Leadership in Education: Theory and Practice*, 2012, Vol. 15(3), pp. 395-401. https://doi.org/10.1080/13603124.2012.661879

[24] D. Hargreaves, "System redesign for system capacity building". *Journal of Educational Administration*, 2011, Vol. 49(6), pp. 685-700. https://doi.org/10.1108/09578231111174820

[25] A. McNeil, D. Prater, D. and S. Buschint, "The effects of school culture and climate on student achievement". *International Journal of Leadership in Education*, 2009, Vol. 12(1), pp. 73-84. https://doi.org/10.1080/13603120701576241

[26] A. Harris, "Leading system-wide improvement". *International Journal of Leadership in Education: Theory and Practice*, 2012, Vol. 15(3), pp. 395-401. https://doi.org/10.1080/13603124.2012.661879

[27] D. Hargreaves, "System redesign for system capacity building". *Journal of Educational Administration*, 2011, Vol. 49(6), pp. 685-700. https://doi.org/10.1108/09578231111174820

[28] C. Bruce and I. Stoodley, "Experiencing higher degree research supervision as teaching". *Studies in Higher Education*, 2013, Vol. 38(2), pp. 226–241. https://doi.org/10.1080/03075079.2011.576338

[29] M. Martinsuo and V. Turkulainen, "Personal commitment, support and progress in doctoral studies". *Studies in Higher Education*, 2011, 36(1), pp. 103-120. https://doi.org/10.1080/03075070903469598

[30] T. Woodall, A. Hiller and R. Sheilagh, "Making sense of higher education: students as consumers and the value of the university experience". *Studies in Higher Education*, 2014, Vol. 39(1), pp. 48-67. https://doi.org/10.1080/03075079.2011.648373

[31] A. Harris, "Leading system-wide improvement". *International Journal of Leadership in Education: Theory and Practice*, 2012, Vol. 15(3), pp. 395-401. https://doi.org/10.1080/13603124.2012.661879

[32] D. Boud and A. Lee, "Peer learning as pedagogic discourse for research education". *Studies in Higher Education*, 2005, Vol. 30(5), pp. 501–516. https://doi.org/10.1080/03075070500249138

[33] K. Lahenius and M. Martinsuo, "Personal study planning in doctoral education in industrial engineering". *European Journal of Engineering Education*, 2010, Vol. 35(6), pp. 607–618. https://doi.org/10.1080/03043797.2010.500719

[34] Le, K. and Tam. V. "How to retain postgraduate students in engineering programmes: a practical perspective". *European Journal of Engineering Education*, 2008, Vol. 33(5–6), pp. 511–524. https://doi.org/10.1080/03043790802564087

[35] A. Kolmos, L.B. Kofoed and X.Y. Du, "PhD students' work conditions and study environment in university- and industry-based PhD programmes". *European Journal of Engineering Education*, 2008, Vol. 33(5–6), pp. 539–550. https://doi.org/10.1080/03043790802588383

[36] R. Kling and G. McKim, "Scholarly communication and the continuum of electronic publishing". *Journal of the American Society for Information Science*, 1999, Vol. *50*(10), pp.

890-906. https://doi.org/10.1002/(SICI)1097-4571(1999)50:10<890::AID-ASI6>3.0.CO;2-8

[37] U-M. Bergroth-Koskinen and R. Seppälä, "Teacher-researchers Exploring Design-based Research to Develop Learning Designs in Higher Education Language Teaching". *Apples – Journal of Applied Language Studies,* 2012, Vol. 6(2), pp. 95–112.

[38] Design-Based Research Collective. "Design-based research: An emerging paradigm for educational inquiry". *Educational Researcher*, 2003, Vol. 32(1), pp. 5-8. https://doi.org/10.3102/0013189X032001005

[39] R. Murray, *How to Write a Thesis*. Open University Press, McGraw-Hill Education, 2009.

[40] A. Lee and B. Kamler, "Bringing pedagogy to doctoral publishing". *Teaching in Higher Education*, 2008, Vol. 13(5), pp. 511-523. https://doi.org/10.1080/13562510802334723

[41] H. Hickson, "Critical reflection: reflecting on learning to be reflective". *Reflective Practice: International and Multidisciplinary Perspectives*, 2011, Vol. 12(6), pp. 829-839. https://doi.org/10.1080/14623943.2011.616687

[42] C. Hilton, W. Motes, and J. Fielden, , "An Experimental Study of the Effects of Style and Organization on Reader Perceptions of Text". *Journal of Business Communication*, 1989, Vol. 26(3), pp. 255-270. https://doi.org/10.1177/002194368902600304

[43] D. Hacker, "*A Writer's Reference"*. Bedford/St. Martin,'s, Boston, the USA, 1999.

[44] H. Uusitalo, H, "*Tiede, tutkimus ja tutkielma"* (Translated by P.L.: Science, research and thesis). WSOY, 1997.

[45] K. Hakkarainen, K. Lonka, K. and L. Lipponen, L., *Tutkiva oppiminen* (Translated by P.L.: Explorative learning), WSOY, 1999.

[46] International Organization for Standardization. http://www.iso.org/iso/home.html (acquired 28.12.2016)

[47] G. Kurz, "Promotion of Pedagogical Abilities of Engineering Lecturers". Published in *TREE – Teaching and Research in Engineering in Europe* (Eds. C. Borri, & F. Maffioli, F.), 2007, Erasmus Thematic Network. Firenze University Press.

[48] P. King and P. Witt, "Teacher Immediacy, Confidence Testing, and the Measurement of Cognitive Learning". *Communication Education*, 2009, Vol. 58(1), pp. 110-123. https://doi.org/10.1080/03634520802511233

[49] A. Franke and B. Arvidsson, "Research supervisors' different ways of experiencing supervision of doctoral students". *Studies in Higher Education*, 2011, Vol. 36(1), pp. 7–19. https://doi.org/10.1080/03075070903402151

[50] P. Lappalainen, *Socially Competent Leadership – predictors, impacts and predictors in engineering*, 2012, Lappeenranta University of Technology, Dissertation Series.

[51] L. Darling-Hammond, "The quiet revolution: rethinking teacher development". *Educational Leadership*, 1996, Vol. 53(6), pp. 4-10.

[52] K. Lahenius and M. Martinsuo, "Personal study planning in doctoral education in industrial engineering". *European Journal of Engineering Education*, 2010, Vol. 35(6), pp. 607–618. https://doi.org/10.1080/03043797.2010.500719

[53] L. Darling-Hammond, "The quiet revolution: rethinking teacher development". *Educational Leadership*, 1996, Vol. 53(6), pp. 4-10.

[54] L. Lambert, "Lasting leadership: towards sustainable school improvement". *Journal of Educational Change*, 2007, Vol. 8(4), pp. 311-23. https://doi.org/10.1007/s10833-007-9046-6

[55] P. Lappalainen, "Integrated Language Education – A Means of Enhancing Engineers' Social Competences". *European Journal of Engineering Education*, 2010, Vol. 35(4), pp. 393-403. https://doi.org/10.1080/03043797.2010.488290

[56] U-M. Bergroth-Koskinen and R. Seppälä, "Teacher-researchers Exploring Design-based Research to Develop Learning Designs in Higher Education Language Teaching". *Apples – Journal of Applied Language Studies,* 2012, Vol. 6(2), pp. 95–112.
[57] B. Paltridge et al., "Doctoral writing in the visual and performing arts: two ends of a continuum. *Studies in Higher Education*, 2012, Vol. 37(8), pp. 989-1003. https://doi.org/10.1080/03075079.2011.562285

7 Author

Pia Lappalainen (pia.lappalainen@aalto.fi) is a Doctor of Science in Technology, an English Major, and a Communications Minor. She currently works as Visiting Professor in Leipzig University in Germany and as Lecturer at Aalto University and Helsinki University in Finland. She is an Organizations and Management researcher with an interest in academic writing. Her mission is to develop doctoral curricula into evidence-based programs that promote researcher motivation and performance.

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Measuring Engineering Faculty Views about Benefits and Costs of Using Student-Centered Strategies

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Eugene Judson
Arizona State University, Tempe, AZ, U.S.A.
Eugene.Judson@asu.edu

Lydia Ross
Arizona State University, Tempe, AZ, U.S.A.

James A. Middleton
Arizona State University, Tempe, AZ, U.S.A.

Stephen J. Krause
Arizona State University, Tempe, AZ, U.S.A.

Abstract—Dispositions of 286 engineering faculty members were assessed to determine views about three student-centered classroom strategies and how frequently faculty used those strategies. The student-centered classroom strategies examined were: using formative feedback to adjust instruction, integrating real-world applications, and promoting student-to-student discussions during formal class time. The Value, Expectancy, and Cost of Testing Educational Reforms Survey (VECTERS), based on expectancy theory, was designed, tested, and validated for this purpose. Results indicate using strategies, such as formative feedback, are significantly tied to perceived benefits and expectation of success. Using student-centered strategies is inversely related to the perceived cost of implementation – with more frequent users perceiving lower cost of time and materials.

Keywords—Student-centered; expectancy theory; formative feedback; engineering education

1 Introduction

As part of an evaluation of a grant funded professional development for engineering faculty, a goal was to detect attitudes of faculty members toward specific practices and compare that to how often the practices were used in classrooms. This is different than evaluating faculty dispositions toward universal concepts such as inquiry learning or constructivism. A review of research led to several related instruments, but none provided the desired functionality. Ultimately, what was found lacking in the canon was an instrument detecting dispositions about specific strategies, particularly for engineering. The desire was to evaluate mindsets regarding specific teaching strat-

egies and begin to understand what variables may be affecting use and nonuse. Because it had been informally observed that engineering professors may integrate one student-centered strategy but not another, it was preferred to evaluate dispositions per strategy. To achieve this goal, a new instrument, based on expectancy theory, was developed: this was the Value, Expectancy, and Cost of Testing Educational Reforms Survey (VECTERS).

In this paper we first provide a reporting of the VECTERS instrument construction and usability that includes its development, theoretical framework, results from testing with a large sample, and its revised form. The three classroom strategies integrated into VECTERS are (1) using formative feedback to adjust instruction (2) integrating real-world applications, and (3) facilitating student-to-student discussion during class time. Second, we address our primary research question: What is the relationship between the use of a particular student-centered strategy and an instructor's disposition regarding, (a) value of the strategy, (b) expectation of the strategy to succeed, and (c) considered cost of using the strategy?

2 Relevant Literature

2.1 Student-Centered Strategies

VECTERS solicits views about the implementation of three student-centered learning strategies. While there are certainly other strategies that fall under this banner, the three selected are pedagogical rallying points promoted within the professional development. In general, the professional development encouraged instructors to move their classrooms toward being environments where students have voice, instructors are responsive to varying student backgrounds, and relevancy between coursework and real-world applications become evident. The limits of this paper do not allow an exhaustive review regarding the three strategies, nevertheless an overview is provided for each.

Formative feedback. The iterative use of formal and informal assessments as a means to support a learner is valuable to the learning process [1]. The concept of learning from one's own attempts and integrating newly developed understandings to existing schema aligns to learners using formative feedback to construct and reconstruct their knowledge and skills [2]. Much of the literature on formative feedback focuses on learners being primary consumers of the feedback and using it to consciously improve their own understanding [3]. In higher education, the activity of formative feedback often ends with the transmission of the feedback from instructor to student, with the onus on students to make improvements [4].

The professional development from which VECTERS emerged focused on deliberate use of formative feedback that is two-way. This emphasizes instructors adjusting instruction based on what they learn about students' comprehension. This moves the dynamic of formative feedback beyond students just studying "what they missed," and places responsibility on faculty to adapt instruction. This may take the form of immediate adaptation of instruction based on responses from electronic response

systems, aka "clickers" [5]. Likewise, formative feedback may manifest through formal collection of what students find to be the "muddiest points" from a lesson followed by altering instruction the next day [6]. This type of instructional responsiveness has shown to positively affect classroom dynamics as well as persistence and achievement in undergraduate engineering courses [7, 8].

Real-world applications. Clearly many facets of an engineering course can be argued as relating to the real world. To provide focus, the definition of real-world applications is described as when an instructor deliberately demonstrates relevance through the integration of problems that are related to real-world problems and/or underscores connections to industry and design. Integration of pedagogy that emphasizes relevance and connections to the real-world have been shown to support student engagement, persistence, and comprehension [9]. Integration of real-world applications moves the responsibility to instructors to be explicit about the real-world application of what is being learned and to clarify how future careers integrate these skills. Real-world connection can manifest on a large scale such as having students form engineering design teams that address community problems [10] or more ordinarily occur as emphasizing real-world connections in the form of contextualized problems and workplace connections [11].

Student to student discussion. When instructors attempt to make their classes more dynamic, getting students to engage in discussion is one of the most popular strategies [12]. The term *discussion* in a college classroom context can have broad interpretations including integrating peer tutors or even interpreting the use of an electronic response system (clicker questions) as a type of discussion. Discussion can also be minimally interpreted as a lecturer asking a series of questions followed by a negligible amount of student responses before proceeding. Here *discussion* is defined as student-to-student discourse that is deliberate, occurring during class time, initiated by the instructor, and focused on furthering understanding of concepts.

Although research supports the efficacy of student-to-student discussion [13], actual use of the strategy in college lecture halls has been slow to progress [14]. Facilitation of discussion that seeds students with questions that flow within the context of a lesson can be helpful in promoting comprehension of new concepts. If students are left to their own devices and merely encouraged to discuss with one another after class, they may not possess necessary linguistic and interactional skills needed to develop shared meaning as they would during facilitated classroom discussion [15].

2.2 Expectancy Theory

Expectancy theory in educational research literature is typically described from student perspective. A student's expectation of how well they will perform on a task is viewed as influencing effort and consequently performance [16]. From an instructor's perspective, expectancy theory frames the effort that must be expended in order to modify instruction. In this context, our expectancy framework is based on an expectation of success, considered value, and an accounting of costs.

Related to the *expectancy of success* is the *value* that individuals place on attainment of an end goal. Attainment value therefore also predicts effort and determination

[17, 18]. Value is sometimes equated as a combination of the value of the input (i.e., costs) *plus* the value of the output. This combines the cost of achieving a goal with the attraction of achieving the goal. We chose to separate these elements of value. The input values are considered *costs* and the outputs are *value*.

Based on expectancy theory, implementation of an educational reform often meets limited success for one or more of three reasons: perception of low value, belief of likely to fail, and assessment of high cost. In many cases the reform is never even transferred from professional development to the classroom because an instructor believes the strategy will have little or no added value for students; or because instructors anticipate instituting the strategy will lead to a less effective learning environment; or simply because instructors consider the expenditure of time and materials too great of a price tag to pay.

3 Research Questions

1. What is the relationship between the value placed on a student-centered teaching strategy and use of the strategy?
2. What is the relationship between the expectation of success with a student-centered teaching strategy and use of the strategy?
3. What is the relationship between the cost associated with implementing a student-centered teaching strategy and use of the strategy?

4 Method

4.1 VECTERS Instrument

The three constructs of VECTERS are based on expectancy theory: *value*, *expectation of success,* and *cost*.

Value. The construct of value is tied to benefit. Implementing a classroom strategy may have benefit for students but it can also be supposed that the strategy can have detrimental effect (i.e., negative value). VECTERS contains eleven value items. Eight of the value items address perceived value (negative and positive) for students; and three of the value items focus on how implementing a strategy may have direct value for the instructor.

Expectancy. The expectancy construct hinges on the vision of the learning environment when the strategy is implemented. These visions, or expectations, of the learning environment outcome are categorized by internal and external attribution types. That is, expectation of success, or lack thereof, might be attributed to students' ability to "handle" the strategy, or might be attributed to the instructor's view of their ability to implement the strategy. Further, expectation of success can be externally attributed to the physical classroom environment – a lecture hall versus a small classroom, or hundreds of students versus a couple of dozen students. VECTERS contains ten expectancy items. Five of these items align with expectancy related to students,

two items focus on expectation of success due to the instructor's capacity, and three items associate expectancy of success with the physical environment or actual content.

Cost. Cost items address the perceived expenditures of implementing a classroom strategy. VECTERS includes five cost items. Among these five items, three address time costs, one item addresses the cost of teaching assistants, and one addresses the cost of overall effort in implementing a strategy.

Overall Design. Twenty-six value, expectancy, and cost items appeared on VECTERS as a mix of both negative and positive statements to which respondents indicated their level of agreement on a Likert four-point scale, from strongly disagree to strongly agree. Engineering faculty responded to the 26 items for each of the three classroom strategies (formative feedback, real-world applications, and initiating student-to-student discussions), thus yielding 78 datum points. An example of the question format is provided in Table 1. This layout was influenced by the work of Abrami, Poulsen, and Chambers [19] who developed the cooperative learning implementation questionnaire (CLIQ).

Table 1. VECTERS example items

Example Items	**Formative Feedback (collecting ongoing feedback from students and altering instruction throughout the semester based on feedback)**	**Real-world Applications (demonstrate relevance, integrate real-world problems, underscore connections to industry and design)**	**Instructor initiated student-to-student discussions during class (focused on furthering understanding)**
Value item: Use of the strategy/tool helps students obtain a deeper understanding of the material.	1 2 3 4	1 2 3 4	1 2 3 4
Expectancy item: Using this strategy/tool may make class too chaotic.	1 2 3 4	1 2 3 4	1 2 3 4
Cost item: It is very difficult to implement this strategy/tool without specialized materials.	1 2 3 4	1 2 3 4	1 2 3 4

4.2 Sample

To acquire an adequate sample for testing VECTERS, an invitation to complete the survey was sent to 19 of the 20 largest colleges of engineering in the United States. One of the 20 largest colleges is the authors' institution and was omitted since several of those faculty members would be requested to complete a subsequent version of VECTERS. Engineering faculty members were invited via email to complete VECTERS online. The invitation was for faculty who taught undergraduate engineering.

A total of 286 responses were received. Though this was suitable to conduct reliability and validity testing, it was not possible to determine the response rate because the request was sent to all available email addresses of engineering faculty members listed on college websites and many of those email addresses were associated with faculty not teaching undergraduate courses.

4.3 Coding

Data from negatively worded value and expectancy items were adjusted so that a 4 on the 1 to 4 scales indicated perception of high value or high expectancy of success. Likewise, data from cost items that implied high expenditure (e.g., implementing this strategy takes too much preparation time) were adjusted so that a response of 4 indicated the respondent viewed cost as being high.

4.4 Internal Consistency

Reliability of VECTERS was assessed by calculating Cronbach's alpha coefficients. The Cronbach's alpha coefficient calculations were first made across all 26-items for all three strategies (i.e., 78 items collectively), and then applied to each of the three sub-instruments (formative feedback, real-world applications, and student-to-student discussion).

4.5 Construct validity

VECTERS construct validity was evaluated by examining relationships between respondents' self-reports of extent to which the three strategies are (1) currently being implemented, and (2) are planned to be implemented. For each strategy, a 2x3 matrix was produced; these indicated relationships between usage (current and planned) with VECTERS mean ratings (value, expectancy, cost). The supposition was that those scoring higher on VECTERS' value and expectancy items, and lower on cost items, would be more likely to currently be integrating a classroom strategy and would be more likely to plan on using the strategy in the future (either initiating or continuing to use). Construct validity was further examined by applying orthogonal (varimax) rotation factor analysis. Analysis was applied to VECTERS' three sub-tests. This supported item reduction analysis and a resulting final version of VECTERS (Appendix).

5 Results

5.1 Relationship of Variables

The internal consistency reliability for VECTERS items was high (Cronbach's α = .90). Cronbach's alpha values for the subsets of formative feedback, real-world appli-

cations, and student-to-student discussion (0.83, 0.76, 0.82, respectively) were also at acceptable reliability levels.

Mean responses regarding the extent to which respondents used a particular strategy, now and in the future, were calculated. Faculty members indicated on a Likert scale if they were using or planned to use each of the three strategies from "not at all" (value = 1) to "entirely" (value = 4). Results indicated real-world applications were used most often by engineering faculty, with the other two strategies approximately equivalent in use (Table 2).

Table 3 provides correlations between mean scores for the constructs of value, expectancy and cost, per each classroom strategy, with the reported level of implementation of the strategy.

Table 2. Current and future use of specific classroom strategies

	Formative Feedback		**Real-world Applications**		**Student-to-student discussion**	
	Mean	***Std. Dev.***	***Mean***	***Std. Dev.***	***Mean***	***Std. Dev.***
Current use	2.45	.90	3.15	.80	2.58	1.1
Future use	2.69	.91	3.31	.73	2.83	1.0

Table 3. Correlations (r-value): Implementation with VECTERS constructs

		Value	**Expectancy**	**Cost**
Formative feedback	Current use	.60**	.53**	-.37**
	Future use	.62**	.50**	-.32**
Real world application	Current use	.44**	.34**	-.27**
	Future use	.40**	.25**	-.13*
Student to student discussion	Current use	.60**	.56**	-.45**
	Future use	.60**	.58**	-.40**

* significant at 0.05 level ** significant at 0.01 level

These relationships met predictions. Among all three classroom strategies, instructors' reported use of the strategy was positively correlated to their dispositions regarding the value of the strategy and their expectation of success. The first of these positive relationships implies that instructors who believe a strategy has value for their students and for themselves uses that strategy more often. Similarly, instructors who expect successful implementation of a strategy are more inclined to use that strategy. The negative relationships found between cost and reported usage met expectations of expectancy theory. These negative relationships imply that higher use correlates with diminished view of the cost of integration.

Because the constructs of value and expectancy were comprised of items that could be further categorized, we drilled down deeper and conducted an exploratory correlation analysis. Again bivariate analyses were examined between the sub-classifications with reported current implementation and with planned implementation. The subcate-

gories and example items are provided in Table 4. Because there were only five cost items, and these were cohesive, no cost subcategories were isolated.

Table 4. Subcategories of value and expectancy items

Construct	Sub-category	n	Example item
Value	value for students	8	Using this strategy/tool fosters positive student attitudes towards learning.
	value for instructor	3	Using this strategy/tool aids my career.
Expectation of success	based on students	6	My students lack the skills necessary to effectively use this strategy/tool.
	based on instructor's ability	2	My knowledge of this strategy/tool is sufficient to implement it successfully.
	based on the physical environment	2	The physical set-up of my classroom is an obstacle to using this strategy/tool.

The greatest predictor for current use (r = 0.6) and planned use (r = 0.61) of formative feedback was the subcategory of seeing value for students. Similarly, current use (r = .48) and planned use (r = .46) of real-world applications was best predicted by seeing it as valuable for students. This finding was consistent for facilitating student-to-student discussions which was also best predicted by seeing value for students (use now, r = .61; planned use, r = .62). Nearly all other subcategories were significantly correlated ($p < .05$) with both current implementation and planned implementation, with r-values ranging from approximately 0.2 to 0.6. The exception was there was no significant relationship between current use (r = .01) or planned use (r = .05) with the belief that using student-to-student discussion had value for the instructor.

5.2 Exploratory factor analysis

Factor analysis was applied to VECTERS' three sub-tests, per the classroom strategies of formative feedback, real-world applications, and student-to-student discussion (26-items per sub-test). Factor analysis was used because of interest in determining how variables grouped on the basis of strength and correlation, and to assess how well those groupings aligned to the designed constructs of value, expectancy, and cost. Based on traditional guidelines of retaining all factors with eigenvalues greater than 1 [20], initial analysis of eigenvalues and the scree plots suggested retaining five factors for formative feedback, accounting for 59.5% of the variance; eight factors for real-world applications, accounting for 65.5% of the variance; and five factors for student-to-student discussion, accounting for 61.6% of the variance. To streamline comparisons, only six factors were retained for real-world applications because the seventh and eighth factors did not contain at least two items loading at a level of 0.6 or above. The total variance accounted for by the six retained factors for real-world applications was 55.0%.

The strongest VECTERS items for each of the three sub-tests are provided in Tables 5, 6, and 7. Four items are shown for each factor unless the factor loading was less than 0.6 - in those cases fewer than four items are presented. To streamline

presentation, the factors are presented across the three tests as A1, A2, A3 . . .B1, B2, . . C1 . . . etc. Items in the third columns are in order of descending relative strength.

Table 5. Formative feedback, factor analysis

Factor	Cumulative Variance %	Items Loading Strongest on this Factor
A1	16.9%	Expectancy – *disagrees that strategy* will not work with my students Expectancy – *disagrees that strategy* interferes with actual learning Value – *disagrees that strategy* hinders ability to fairly assess students Expectancy – *disagrees that strategy* may make class too chaotic
A2	32.8	Value – motivates students Value – helps students obtain deeper understanding Value – increases student comprehension Value – promotes valuable collegiality among students
A3	44.2	Cost – takes too much prep time Cost – requires a lot of effort Cost – difficult to implement without specialized materials Cost – requires considerable use of TAs
A4	52.0	Expectancy – I understand this strategy well enough to implement successfully Expectancy – My knowledge of this strategy is sufficient to successfully implement
A5	59.5	Value – using this strategy aids my career Value – is aligned with goals of my college and university

Table 6. Real-world applications, factor analysis

Factor	Cumulative Variance %	Items Loading Strongest on this Factor
B1	15.4%	Value – the strategy is a valuable instructional approach Expectancy – *disagree that strategy* interferes with actual learning Expectancy – *disagrees that strategy* will not work with my students Value – *disagrees that strategy* hinders learning of bright students
B2	25.9	Cost – takes too much prep time Cost – requires a lot of effort Cost – difficult to implement without specialized materials Cost – requires considerable use of TAs
B3	34.1	Value – increases student comprehension Value – motivates students
B4	41.7	Expectancy – My knowledge of this strategy is sufficient to successfully implement Expectancy – I understand this strategy well enough to implement successfully
B5	48.6	Value – using this strategy aids my career Value – is aligned with goals of my college and university
B6	55.0	Expectancy – *disagrees that* physical set-up of my classroom is an obstacle Expectancy – *disagrees that* there are too many students to implement successfully

Table 7. Student-to-student discussions, factor analysis

Factor	Cumulative Variance %	Items Loading Strongest on this Factor
C1	19.4%	Value – motivates students Value – increases student comprehension Value – fosters positive attitudes towards learning Value – promotes valuable collegiality among students
C2	35.2	Expectancy – *disagrees that strategy* will not work with my students Expectancy – *disagrees that strategy* interferes with actual learning Expectancy – *disagrees that strategy* inappropriate for the subject taught Expectancy – *disagrees that* students lack necessary skills to be effective
C3	47.4	Cost – takes too much prep time Cost – difficult to implement without specialized materials Cost – requires considerable use of TAs Cost – requires a lot of effort
C4	55.2	Expectancy – My knowledge of this strategy is sufficient to successfully implement Expectancy – I understand this strategy well enough to implement successfully
C5	61.6	Expectancy – *disagrees that* physical set-up of my classroom is an obstacle Expectancy – *disagrees that* there are too many students to implement successfully

A crosswalk examination of the factor analyses presented in Tables 5, 6, and 7, led to connections and themes becoming evident. A dimension termed "functionality" is represented in factors A1, B1, and C2. These three factors share items that point toward a belief that the strategy simply will work with students and a dismissal of the notion that the strategy somehow interferes with learning.

Also cutting across all three strategies is a dimension referred to as "expense." The expense dimension (represented by factors A3, B2, and C3) is present among all three of the strategies and the exact same four cost items rank highest across all three strategies. The only cost item that did not load heavily in the expense dimension was the statement that "there is too little time available during class to implement this strategy effectively." The implication here is that the commodity of class time is viewed differently than the cost of out-of-class expenditures such as teaching assistants (TAs), materials, and preparation time. This may also speak to high variability in the amount of minutes allotted per week across the different colleges and courses.

A third important dimension is termed "student benefit." This is represented by factors A2, B3, and C1. This dimension corresponds to the sentiment that use of a strategy aids student comprehension and motivates students. A dimension of "personal ability" also cut across all three strategies and is represented by A4, B4, and C4. Finally, other dimensions cutting across at least two strategies but accounting for comparatively less of the variance than those listed above are the following. Factors A5 and B5 represent a dimension of "job expectation." Additionally, factors B6 and C5 represent a dimension of "physical environment."

6 Conclusion

In response to the primary research questions, this study indicated strong relationships exist between the use of a student-centered strategy and an engineering instructor's disposition about that strategy. This supports the theoretical framework of expectancy theory. More importantly, the findings underscore how attitudes and perceptions can act as gatekeepers. An implication here is that effective professional development must address not just the logistics and mechanics of integrating classroom lessons, but must tackle the difficulty of affecting attitude.

This study also yields an assessment tool with broad application potential. Item analysis pointed toward cohesiveness and strong interconnections. The examination of construct validity played out well for value, expectancy, and cost. The cost-decreases-with-usage relationship indicates that using a strategy is negatively related to perception of high cost. This finding aligns to research indicating that when people perceive a reform to have first-order barriers (i.e., external cost) they are less likely to implement; however users of a reform tend to minimize first-order barriers and focus on the more important second-order barriers such as views about effectiveness and potential for success.

VECTERS is seen has having two useful future roles. First, as a diagnostic tool for engineering educators. However, this need not be limited to engineering faculty since the three classroom strategies are supported across multiple disciplines. Using VECTERS as one means of evaluating the dispositions of faculties over time can help to pinpoint mindsets and experiences that are hampering implementation of strategies. The revised VECTERS (Appendix) can be used in whole. Researchers adapting the instrument for their needs may choose to reduce and/or interchange the topics and then evaluate if the new instrument persists with sufficient reliability and validity strength. A second useful role for VECTERS may be as a tool that helps to facilitate discussion about teaching. In our professional development, items were selected from VECTERS as seeds of conversation among faculty members. Having meaningful discourse about the specifics of value, expectation, and cost, enriches dialogue. This type of deeper discussion aids instructors in developing introspection regarding their own beliefs and perceived obstacles of implementation.

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8 References

[1] D. R. Sadler, "Formative Assessment: revisiting the territory," *Assessment in Educ.: Principles, Policy & Practice*, vol. 5, no. 1, pp. 77-84, 1998.

[2] D. L. Butler and P. H. Winne, "Feedback and Self-Regulated Learning: A Theoretical Synthesis," *Review Educ. Research*, vol. 65, no. 3, p. 245, 1995. https://doi.org/10.3102/00346543065003245
[3] M. Yorke, "Formative assessment in higher education: Its significance for employability, and steps towards its enhancement," *Tertiary Educ. and Management*, vol. 11, no. 3, pp. 219-238, 2005. https://doi.org/10.1080/13583883.2005.9967148
[4] D. J. Nicol and D. Macfarlane-Dick, "Formative assessment and self-regulated learning: a model and seven principles of good feedback practice," *Studies in Higher Educ.*, vol. 31, no. 2, pp. 199-218, 2006. https://doi.org/10.1080/03075070600572090
[5] Author, 2002.
[6] Author, 2014a.
[7] Author, 2013.
[8] Author, 2014b.
[9] D. Bairaktarova, M. Pilotte and I. Tetzloff, "Relevance-based learning in students' early engineering education experience,". *in IEEE Frontiers in Educ. Conf.*, 2014, pp. 1-3. https://doi.org/10.1109/fie.2014.7044008
[10] E. J. Coyle, L. H. Jamieson, and W. C. Oakes "EPICS: Engineering projects in community service," *Int. J. Eng. Educ.*, vol. 21, no. 1, pp. 193-150, 2005.
[11] D. Jonassen, J. Strobel and C. Lee, "Everyday Problem Solving in Engineering: Lessons for Engineering Educators," *J. Eng. Educ.*, vol. 95, no. 2, pp. 139-151, 2006. https://doi.org/10.1002/j.2168-9830.2006.tb00885.x
[12] E. J. Dallimore, J. H. Hertenstein and M. B. Platt, "Classroom participation and discussion effectiveness: student-generated strategies," *Communication Educ.*, vol. 53, no. 1, 2004. https://doi.org/10.1080/0363452032000135805
[13] C. Garside, "Look who's talking: A comparison of lecture and group discussion teaching strategies in developing critical thinking skills," *Communication Educ.*, vol. 45, no. 3, pp. 212-227, 1996. https://doi.org/10.1080/03634529609379050
[14] M. Watts and W. Becker, "A little more than chalk and talk: Results from a third national survey of teaching methods in undergraduate economics courses,," *J. Econ. Educ.*, vol. 39, no. 3, pp. 273-286, 2008. https://doi.org/10.3200/JECE.39.3.273-286
[15] R. A. Ellis, P. Goodyear, R. A. Calvo and M. Prosser, "Engineering students' conceptions of and approaches to learning through discussions in face-to-face and online contexts," *Learning and Instruction*, vol. 18, no. 3, pp. 267-282, 2008. https://doi.org/10.1016/j.learninstruc.2007.06.001
[16] A. Kirn and L. Benson, "Engineering students' perceptions of the future: Exploratory instrument development," presented at the 122nd ASEE Annu. Conf. & Exposition, Seattle, WA, 2015 https://doi.org/10.18260/p.23979
[17] J. Shah and E. T. Higgins, "Expectancy × value effects: Regulatory focus as determinant of magnitude and direction," *J. of Personality and Social Psychology*, vol. 73, no. 3, pp. 447-458, 1997. https://doi.org/10.1037/0022-3514.73.3.447
[18] T. M. Shu and S. F. Lam, "Are success and failure experiences equally motivational? An investigation of regulatory focus and feedback," *Learning and Individual Differences*, vol. 21, no. 6, pp. 724-727, 2011. https://doi.org/10.1016/j.lindif.2011.08.002
[19] P. C. Abrami, C. Poulsen and B. Chambers, "Teacher motivation to implement an educational innovation: factors differentiating users and non-users of cooperative learning," *Educ. Psychology*, vol. 24, no. 2, pp. 201-216, 2004. https://doi.org/10.1080/0144341032000160146

[20] H. F. Kaiser, "The Application of Electronic Computers to Factor Analysis," *Educ. and Psychological Measurement*, vol. 20, no. 1, pp. 141-151, 1960. https://doi.org/10.1177/001316446002000116

9 Authors

Eugene Judson is an Associate Professor of science education and educational policy with the Mary Lou Fulton Teachers College at Arizona State University, Tempe, AZ, USA (eugene.judson@asu.edu).

Lydia Ross is a doctoral student pursuing a PhD in the Educational Policy and Evaluation program at Arizona State University, Tempe, AZ, USA (llross1@asu.edu).

James A. Middleton is a Professor of engineering education in the School for Engineering of Matter, Transport and Energy within the Ira A. Fulton Schools of Engineering at Arizona State University, Tempe, AZ, USA (James.Middleton@asu.edu).

Stephen J. Krause is a Professor of materials science and engineering in the School for Engineering of Matter, Transport and Energy within the Ira A. Fulton Schools of Engineering at Arizona State University, Tempe, AZ, USA (skrause@asu.edu).

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10 Appendix

VECTERS 2.0, (items after factor analysis reduction)
Contact authors for a complete version including demographic questions.

1 = Strongly Disagree 2 = Disagree 3 = Agree 4 = Strongly Agree

	Formative Feedback (collecting ongoing feedback from students and altering instruction throughout the semester based on feedback)	**Real-world Applications (demonstrate relevance, integrate real-world problems, underscore connections to industry and design)**	**Instructor initiated student-to-student discussions during class (focused on furthering understanding)**
2. I understand this strategy well enough to implement it successfully. (E)	1 2 3 4	1 2 3 4	1 2 3 4
3. My knowledge of strategy is sufficient to implement successfully. (E)	1 2 3 4	1 2 3 4	1 2 3 4
4. My students lack the skills necessary to effectively use this strategy. (E)	1 2 3 4	1 2 3 4	1 2 3 4
5. Using this strategy may make class too chaotic. (E)	1 2 3 4	1 2 3 4	1 2 3 4
6. Too many students in class to implement strategy effectively. (E)	1 2 3 4	1 2 3 4	1 2 3 4

7. Using this strategy interferes with actual learning. (E)	1	2	3	4	1	2	3	4	1	2	3	4
8. This strategy is inappropriate for the subject I teach. (E)	1	2	3	4	1	2	3	4	1	2	3	4
9. This strategy will not work with my students. (E)	1	2	3	4	1	2	3	4	1	2	3	4
10. Physical set-up of classroom is an obstacle to using this strategy. (E)	1	2	3	4	1	2	3	4	1	2	3	4
11. Use of this tool/strategy hinders learning of bright students (V)	1	2	3	4	1	2	3	4	1	2	3	4
13. Using this strategy aids my career. (V)	1	2	3	4	1	2	3	4	1	2	3	4
14. This strategy is a valuable instructional approach. (V)	1	2	3	4	1	2	3	4	1	2	3	4
15. Helps students obtain a deeper understanding of the material. (V)	1	2	3	4	1	2	3	4	1	2	3	4
16. Use of this strategy hinders my ability to fairly assess students. (V)	1	2	3	4	1	2	3	4	1	2	3	4
17. Using this strategy promotes valuable collegiality among students. (V)	1	2	3	4	1	2	3	4	1	2	3	4
18. This strategy is aligned with goals of my college and university. (V)	1	2	3	4	1	2	3	4	1	2	3	4
19. Using strategy fosters positive student attitudes towards learning. (V)	1	2	3	4	1	2	3	4	1	2	3	4
20. Increases students' comprehension and achievement. (V)	1	2	3	4	1	2	3	4	1	2	3	4
21. Using this strategy motivates students. (V)	1	2	3	4	1	2	3	4	1	2	3	4
22. The effort involved in implementing this strategy is great. (C)	1	2	3	4	1	2	3	4	1	2	3	4
23. Difficult to implement this strategy without specialized materials. (C)	1	2	3	4	1	2	3	4	1	2	3	4
24. Implementing this strategy requires considerable use of TA's. (C)	1	2	3	4	1	2	3	4	1	2	3	4
26. Implementing this strategy takes too much preparation time. (C)	1	2	3	4	1	2	3	4	1	2	3	4

A Review of Embedded Systems Education in the Arduino Age: Lessons Learned and Future Directions

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Mohammed El-Abd
American University of Kuwait, Kuwait City, Kuwait
melabd@auk.edu.kw

Abstract—In this paper, the subject of embedded systems education in the Arduino age is examined. Arduino is an open-source microcontroller platform that has been widely popular in the past decade among hobbyists and academics. Arduino is increasingly being adopted in courses that span different disciplines in schools and universities. As a result, numerous papers are being published every year in different engineering education conferences and journals reporting the integration of Arduino in teaching. In this work, the impact of Arduino on embedded systems education is investigated. First, challenges facing embedded systems education are identified from the literature. Second, different Arduino teaching integration methodologies reported in the literature are surveyed and analyzed. Third, the question whether Arduino successfully addresses embedded education challenges or not is discussed taking both surveyed findings and recent market trends into consideration. Finally, a number of open-ended research directions are proposed.

Keywords—Arduino, engineering education, embedded systems, microcontrollers, open educational resources, open source hardware, open source software.

1 Introduction

Embedded systems in the engineering domain refer to systems that do not necessarily have a computational task; yet they are controlled by a computing entity. This computing entity could be a microprocessor, a microcontroller, a Field programmable Gate Array (FPGA), or a Digital Signal Processor (DSP). Nowadays, these are such ubiquitous technologies that are being used in more applications than anyone can imagine. Such applications range from household appliances and office equipment, home automation, consumer electronics, to the automotive industry and beyond.

The joint ACM/IEEE task force developed a 2016 draft model computer engineering curriculum[1] in which the knowledge area of embedded systems could be allocated up to 40 core hours. The embedded systems knowledge area covers many topics containing relevant tools, software techniques, input/output, serial communication, time measurement, and data acquisition. The number of hours allocated to this knowledge

[1] https://www.computer.org/web/peb/curricula

area in 2016 was doubled from 2004 as a reflection of directions in which the discipline has evolved.

The work in [1] identified seven different models for embedded systems education. They identified which models were being used by surveyed universities in North American, Europe, and the Far East. These models ranged from teaching individual embedded systems courses in undergraduate level, graduate level, to developing complete embedded systems programs.

Embedded computing is divided into a number of categories in [2]. One category, which is the focus of this work, is small and single microcontroller applications. The authors stated that this topic serves well as an introduction to other embedded courses. The authors motivated their students with the use of exciting course projects. One major challenge for this type of a course as identified by the authors is that students do not like "heavy" engineering processes and that they tend to skip important software engineering practices to meet deadlines.

In general, teaching embedded systems could be *hardware-oriented*, *software-oriented*, or *hardware-software integration* [3]. The authors presented how an "Introduction to Embedded Systems" course should fit in the engineering curriculum, a placement similar to what was proposed in [4]. Moreover, the authors suggested that in *hardware-oriented* teaching, students should be given the opportunity to select and/or buy their own development kits at the beginning. In addition, the authors identified embedded engineering education challenges to be *student-related* (lack of knowledge, lack of motivation, planning skills …), *lecture-related* (spanning of several fields, dynamic progress of technology, hardware and software compatibility …), and *course-content related* (limited-time, a discipline not well-defined)

A research study was performed in [5] to investigate how to transform academic teaching to better equip students with design skills and fulfill industry needs. An interesting finding was that both academics and professionals agreed that the students' lack of motivation is due to the teaching style. In addition, results clearly showed that students are more interested to learn when presented with hands-on projects and practical applications. It was concluded that educators must focus on practice rather than theory in the classroom.

A challenge facing the industry and academia collaboration was highlighted in [6]. The authors pointed that nowadays the technology cycle is shorter than the engineering education time, which means that what the industry needs now, should have been already provided by education in the past. This is the same *lecture-related* challenge (dynamic progress of technology) highlighted in [3]. The authors pointed out that one solution could be having early engineering education in basic and high schools [7]. Several other challenges identified by the authors included: the incorporation of such concepts as system integration, testing, and versification, the used learning platform, the adopted educational methodology (classes, laboratories, ...) and the followed evaluation and assessment scheme.

In addition, the same authors developed their own embedded engineering learning platform (E2LP) [6, 8]. The platform was an attempt to address the issues previously raised while supporting 5 learning objectives covering embedded microprocessors, DSP, FPGAs, networks, and system integration. The authors use a single hardware

platform through all their courses to considerably reduce the learning time at the beginning of each course. Again, this also addresses one of the *lecture-related* challenges (hardware and software compatibility) highlighted in [3].

The idea to develop a single platform for all courses (E2LP) was followed to overcome difficulties with laboratory classes highlighted in [9]. These difficulties included the time needed to learn new tools, the time needed to acquire and/or fabricate new parts, the support needed for design tools, the little reuse of equipment across different courses, the time needed to manage projects. Authors pointed out that using different hardware platforms and laboratory tools across different courses can introduce around 30% overhead in both time and effort in order to learn the new tools.

Fig. 1 illustrates different embedded education challenges identified in the literature. The figure adopts the same classification in [3] while adding a new class and highlighting how similar challenges were identified in other works.

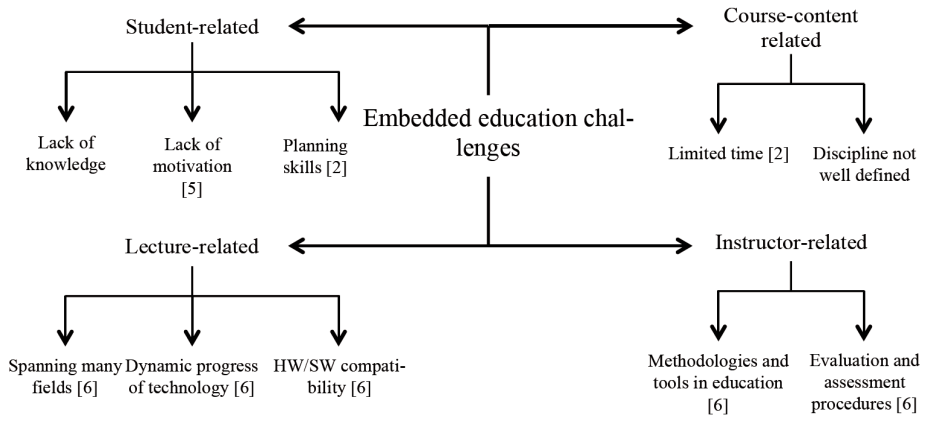

Fig. 1. Embedded education challenges.

The added class in Fig. 1, *instructor-related*, refers to decision that need to be taken by the instructor prior or during the course. This is based on two challenges identified in [6]. One challenge is the methodologies and tools for education, which highlights the need to carefully design the course structure and select the appropriate learning platform. Note that the platform selection could be also tied to the HW/SW compatibility challenge. The second challenge is the evaluation and assessment procedure adopted by the instructor in the course.

This review focuses on the use of Arduino in embedded systems courses. To the best of our knowledge, such an investigation has not been carried before in the literature. In specific, the goal of the study is to address the following questions:

- How was Arduino adopted in embedded education?
- Does the use of Arduino address the current challenges faced by embedded engineering education?
- What future research directions could be investigated?

The rest of the paper is divided as follows: Section 2 gives a brief background about Arduino. Previous works on the use of Arduino in embedded engineering education are analyzed in Section 3. Section 4 summarizes the lessons learned and proposes future research directions. Finally, the paper is concluded in Section 5.

2 The Arduino Platform

The Arduino project was first developed in Italy in 2005. As defined on their website[2] "Arduino is an open-source electronics platform based on easy-to-use hardware and software". The Arduino platforms were built to address several issues in other microcontroller products making it more appealing for hobbyists, students, and teachers. It has the advantages of low cost, cross-platform, simplicity of programming, and open-source extendable software and hardware.

Arduino products are based on the 8-bit ATmega microcontrollers. Boards are equipped with a large number of digital and analog IO pins, serial communication modules, USB connection, and ICSP capability. Arduino boards are easily interfaced with external components for data acquisition and control applications. All Arduino boards could be connected to a number of shields developed for different applications.

As a measure of the popularity of Arduino, Fig. 2 illustrates the results extracted by Google Trends regarding searches for three keywords, namely: Arduino, Raspberry Pi, and the PIC microcontroller. An interesting behavior to note is the general continuous increase of the number of searches for Arduino and Raspberry Pi with Arduino having a higher number. On the other hand, the number of searches for the PIC microcontroller is gradually decreasing over the past five years.

Moreover, as Arduino became more and more popular among academics, the number of publications involving the Arduino platform has considerably increased over the years. Fig. 3 illustrates the number of Arduino-related publications in the following engineering education conferences: American Society for Engineering Education (ASEE), Frontiers in Education (FIE), IEEE Teaching, Assessment, and Learning for Engineering (TALE), and IEEE Global Engineering Education Conference (EDUCON). These publications either report using Arduino in education (in primary schools, high schools and universities), introducing new Arduino educational boards, recommending its use, or just acknowledging the technology.

Some programs offer complete courses for learning Arduino. For example, two courses are dedicated for learning Arduino and its programming environment, and interfacing principles at the University of California, Irvine[3] in an Internet-of-Things (IoT) specialization.

Arduino is gaining interest from the industry as well. Referring to an embedded systems market study carried by UBM[4] in 2014, 19% of the surveyed professionals are considering the use of Arduino in their next embedded project.

[2] https://www.arduino.cc/en/Guide/Introduction
[3] https://www.coursera.org/specializations/iot
[4] http://bd.eduweb.hhs.nl/es/2014-embedded-market-study-then-now-whats-next.pdf

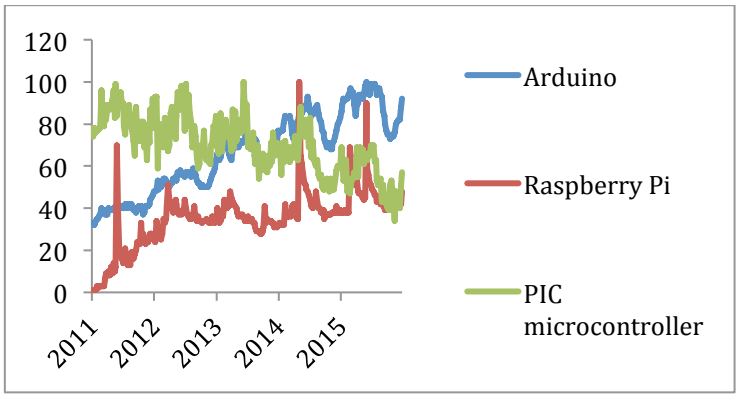

Fig. 2. Google trends extracted history of searches for the past 5 years.

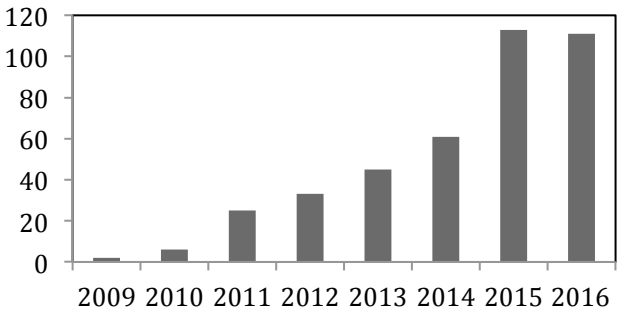

Fig. 3. Number of Arduino-related publications per year.

3 Arduino In Embedded Systems Education

This section analyzes previous works using Arduino in teaching embedded systems. Other works, which might not be cited, apply Arduino in freshmen engineering, adopt it in other disciplines, develop Arduino-based remote laboratories, implement Arduino-based educational kits, or use Arduino in pre-university education.

Table 1 provides a comparison among different Arduino integration methods in embedded systems courses. The comparison is based on three metrics: *Platform adoption* (Single vs. Multiple), *Project type* (Free vs. Restricted), *Programming knowledge* (Low-level vs. High-level vs. Both). These metrics are selected to reflect the level to which Arduino was injected into the course. A "Free" project type refers to students selecting their own project topics and/or technologies while "Restricted" means that these are enforced by the instructor [15]. In addition, Table 1 reports the course level, the assessment scheme followed by different works, and any reported advantages and/or concerns.

Table 1. Arduino integration methodologies comparison

Work	Course Level	Platform	Project	Program	Assessment	Advantages	Concerns
10	Junior	Arduino	Free	C	Reports + Presentations + Video Demos	Student's motivation; Accessibility	Timers inaccessible
11	Third year	Arduino + FPGA + PIC	Free	C	Presentations + Demo	Interesting varied and projects; Ease of interfacing external chips	Low-level concern; Student's contribution; missing topics
12	Third year	Arduino + Raspberry Pi + BeagleBone	Free	C	Reports + Presentations + Demo	Improved system design capabilities	NR
13	Senior	Arduino + FPGA	Free	C	Reports + Presentations + Demos	Ease of use; Less development time; Logistical issues	NR
14	Second year	Arduino	Free	C	Reports + Presentations + Demos	Increase in success rate	Low-level concern; Student's contribution
15	Third year	PIC + Arduino	Free	Assembly + C	Reports + Presentations + Demos	Interesting projects; Improved performance in capstone	Student's contribution
16	Junior	Arduino + Suggested	Free	C + Assembly	Reports + Presentations	Support material; little lab space;	Student's contribution; Hidden code; Clocking applications
17	Master	Arduino	Restricted	C	Reports + Presentations + Video Demos + Self- and Peer-assessment	Increased satisfaction; Increase in success rate	NR

Inspecting the first metric in Table 1 shows that Arduino was the *single* learning platform adopted throughout the course in [10, 14, 16, 17]. In [11], Arduino was compared against FPGAs and the PIC microcontroller used in previous course offerings. In [12], the Arduino, Raspberry Pi, and BeagleBone were used in the embedded systems and capstone courses. In [13], both Arduino and FPGAs are concurrently used in the course delivery. In [15], the main platform adopted was the PIC microcontroller, while Arduino was the popular platform selected by students in implementing their course projects. In [16], students were encouraged to use another microcontroller in the project but Arduino was still allowed. An interesting observation is that over 90% of students, when given the choice, select Arduino to implement their projects [11, 15].

For the course project metric, work in [17] enforced the project topic in home-management Systems. All other works provided the students with the freedom to select their project topic. This usually resulted in increased students' enthusiasm and

motivation as well as more creative projects being developed. This could be a direct result of students working on projects they feel passionate about.

Projects based on integrating already available resources were accepted in [11] to improve system integration skills. In [12], same authors reported that the main microprocessors course learning objective is to "create". Hence; the assessment scheme was updated with a deliverable document distinguishing the students' contribution from used resources. Authors reported the improvement of the students' system design capabilities.

In most previous works, Arduino was programmed using its C-like language; thus only providing high-level knowledge. The single exception was for [16], in which Assembly was used during the final stage of the course using AVR studio[5] but not necessarily for Arduino. Assembly usage in [15] was for the PIC microcontroller during the course. However, Arduino was always programmed using C in the project. This still offers both low-level and high-level knowledge as in [16]. Both approaches address "the lack of low-level knowledge" concern raised in [11, 14].

As for the effect on students' performance, the percentage of students successfully passing the course in [14] has increased, after using Arduino, from 61% to 92% in module I and from 66% to 93% in module II. In [15], a study conducted over three consecutive semesters revealed that 94% of students selected Arduino for their course projects. Out of these students, 59% continued to use Arduino in their capstone courses resulting in an improved performance. In [17], the cooperative learning methodology, with the use of Arduino, resulted in improving the academic success of students with 93.5% scoring above 85%.

One cited advantage in [13] is the reduction in project development time allowing for post evaluation, and increasing code complexity. Same advantage was highlighted in [15], as using Arduino allowed students to develop fully functioning systems with the appropriate documentation in less time.

The concern highlighted in [10] about timers was also identified in [16]. The concern was addressed by changing the course delivery method in [16] to use AVR Studio towards the end of the course in order to program Arduino in low-level. An important advantage reported in [16] is the need for little lab space. As students can buy their own Arduino platforms at an affordable price, there becomes no need to purchase and install dedicated laboratory equipment for the course.

Finally, one major advantage identified in most of these works is the ease of learning and using the Arduino platform (Accessibility in [10], Ease of interfacing external chips in [11], Ease of use in [13], and Support material in [16]). With the availability of numerous online forums and groups, tutorials, and previously implemented projects, it becomes easier for students to learn such a platform in less time.

4 Lessons Learned and Future Directions

In this section, and based on the literature and recent market trends, the question whether Arduino addresses embedded education challenges is investigated. Moreover,

[5] http://www.atmel.com/Microsite/atmel-studio/

future research directions are identified to better assess the current state and to improve Arduino integration in teaching.

The Student-related Challenges: A commonly reported advantage, when using Arduino, is the increase in students' motivation and interest. This directly addresses the *student-related* challenges in [3]. This observation is also directly related to the conclusions reached and actions recommended in [5]. Such an advantage does not only help in improving students' performance in classes [14, 15], but it can also attract students to the engineering major. For example, switching the course technology to Arduino in [18] has resulted in minimizing the students' evasion rate from the computer engineering program.

Another *student-related* challenge is the student's planning skills, which was also emphasized in [2]. This is implicitly handled by using Arduino as developing a complete system with this platform can take less development time in general [13, 15]. This provides the students with more time for code maintenance, debugging, and documentation.

The Lecture-related (Spanning many Fields) Challenge: One challenge is the wide range of topics to be covered in embedded systems courses. These topics are divided across 13 units (12 core + 1 supplementary) under the embedded systems knowledge area in the 2016 ACM/IEEE model curriculum. Arduino could be used to cover most of these topics with varying depths. Units are presented in Table 2 with possible degrees of coverage.

Table 2. Arduino coverage of embedded systems units

Number	Knowledge Unit	Coverage
1	History and overview	Full
2	Relevant tools, standards, and/or engineering constraints	Full
3	Characteristics of embedded systems	Full
4	Basic SW techniques for embedded applications	Full
5	Parallel input and output	Full
6	Asynchronous and synchronous communication	Full
7	Periodic interrupts, waveform generation, time measurement	Medium
8	Data acquisition, control, sensors, actuators	Full
9	Implementation strategies for complex embedded systems	Low
10	Techniques for low power generation	Medium
11	Mobile and networked embedded systems	Full
12	Advanced input/output topics	Medium
13	Computing platforms for embedded systems	Low

"Full" coverage is for units that could be covered using Arduino and ready-made shields even if this requires a deeper study of the shield and its software library.

"Medium" coverage in units 7, 10, and 12 is chosen due to the difficulty of accessing a number of microcontroller hardware components unless Assembly is used.

"Low" coverage is selected for unit 9 as it is difficult to use Arduino to teach embedded operating systems [11]. Further studies are required to investigate if such

systems currently available for Arduino[6,7] make it possible to cover this topic. "Low" coverage is selected for unit 13 as it is not possible to teach GPUs, FPGAs, or multi-core processors using Arduino.

This challenge could be also addressed on a different level by introducing interdisciplinary subjects and projects. Interfacing Arudino with MATLAB [19-20], LabView [21-23], and its use in the IoT domain [24-26] paves the way for unlimited possibilities of multidisciplinary applications.

The Lecture-related (HW/SW Compatibility) and the Instructor-related (Tools for Education) Challenge: The *first* question faced in a microcontroller course and one challenge highlighted in [6], is "What is the appropriate learning tool to be selected?" The existence of many microcontroller products renders the platform selection to be a critical step. It is safe to assume that this selection should be made to serve the industry needs. An embedded market study carried by Gartner[8] in 2014 revealed that 8-bit microcontrollers have around 40% market share. In that category, Microchip and Atmel were numbers 1 and 4 in the market. Recent Microchip acquisition of Atmel[9] makes the PIC and ATmega (on which the Arduino is built) microcontrollers the most dominant. Hence, if an 8-bit microcontroller is selected for embedded systems courses, and from a purely industrial point of view, PIC and Arduino could prove to be the best options. An interesting observation is that in [15], PIC is used in the course while Arduino is mostly selected by students in the project. However, in [16], Arduino is used in the course while PIC is one optional microcontroller suggested for the project.

This learning platform challenge was the focus of a study comparing six different embedded platforms used in freshmen engineering [27]. This was based on four metrics: *hardware-intensive*, *software-intensive*, *ease-of-implementation*, and *course/application relevance*. Arduino was found to be one of the platforms suited for such courses. In order to answer the "platform selection" question, an interesting future research direction is to conduct a similar study, comparing different microcontroller platforms (PIC, Arduino …) and/or microprocessor boards (Raspberry Pi, BeagleBone, Intel Galileo …) for embedded systems courses. Metrics could be based on the topics covered by the ACM/IEEE model curriculum. A different direction is to design your own board and customize it to the learning objectives of your course. However, it would be difficult to provide these boards for the students outside open lab hours.

The methodology of using a single platform through an educational curriculum [6, 8] could be applied using Arduino. Arduino has been adopted in many courses that span the engineering curriculum including Introduction to Engineering [18, 28-33], Chemistry [34-35], Physics [36-38], Electronics [39-41], Control and Robotics [19-20, 42-43], Fuzzy Logic [44], and DSP [45]. Arduino with its overall simplicity, availability of on-line resources, ease of acquiring parts, and fast prototyping process

[6] https://bitbucket.org/ctank/ardos-ide/wiki/Home
[7] https://create.arduino.cc/projecthub/feilipu/using-freertos-multi-tasking-in-arduino-ebc3cc
[8] http://ww1.microchip.com/downloads/en/Market_Communication/MicrochipPresentation_Evolution of 8-bit MCUs_Final.pdf
[9] http://www.microchip.com/announcements/microchip-technology-inc-acquires-atmel

overcomes many of the difficulties stated in [9]. However, this raises the question if adopting a single platform through the entire curriculum would limit the students' knowledge.

Revisiting the E2LP platform [6, 8], a number of its presented learning outcomes could be fulfilled by Arduino with the exception of the FPGA ones. Atmega could be adopted to teach microcontrollers using Assembly if required. Network shields could be used to illustrate different networking applications. The DSP shield in [45] could be used for DSP applications. One major concern would be if using already manufactured shields would provide proper learning tools. An interesting direction would be to propose project ideas for building Arduino shields. This would give the students the opportunity to design hardware circuits and experience low-level programming for developing the accompanied libraries. Such developed Arduino shields could be used in other courses; thus improving the overall learning experience.

The Lecture-related (Technology Cycle or Dynamic Progress of Technology) Challenge: Teaching embedded engineering in schools [7] is identified as one of the solutions to address this problem [3, 6, 8]. Arduino is already contributing in that direction as it has been adopted in pre-university education [46-50]. The work in [51] presented a high-school outreach program developed in New Zealand. Part of the program provided teachers with Arduino kits and a suggested set of experiments to be conducted at school. This helped to increase enrollment figures by 36% in one year.

The Development vs. Recombination Challenge: This challenge identified in [6] highlights the need to find the right balance between the students developing their own code and reusing existing codes. Such a challenge falls in the classification of Fig. 1 under both methodologies for education (Teaching how to recognize reuse opportunities) and evaluation and assessment procedures (How to assess Arduino-based projects?). Same issues were raised [11-12, 14, 16] as authors discussed concerns about the *lack of low-level experience* and the *reuse of existing Arduino code*.

According to the 2015 UBM[10] embedded market study; around 75% of embedded applications are programmed in C/C++ while only around 3% are programmed in Assembly. In addition, when asked about the programing language most likely to be used in the next application, around 83% chose C/C++ while only 2% chose Assembly. Such staggering numbers raises the question of how important the teaching of low-level programming in embedded systems courses still is.

This brings us to the *second* question: If Arduino is used in embedded systems education, how can one balance low-level vs. high-level knowledge? And how much low-level programming is required? Answers to these questions could very much depend on the course structure. Is it a lecture-based course? Is there a laboratory component involved? Is it a project-based course? Or is it a combination of all of these? As mentioned in [6], the use of remote laboratories can also improve engineering education. Some works on Arduino-based remote laboratories could be found in [52-54]. Note that Arduino could be programmed with Assembly using AVR studio [16]. This has the benefit of introducing the students to a new software tool other than the Arduino IDE used for programming the Arduino in its C-like language..

[10] http://webpages.uncc.edu/~jmconrad/ECGR4101-2015-08/Notes/UBM Tech 2015 Presentation of Embedded Markets Study World Day1.pdf

The same 2015 UBM market study showed that 86% of developed applications reused previously written code, some of which was open-source. This shows that reusing Arduino code is a behavior that students will face in industry and it will enhance the students' system integration capabilities as identified in [11]. However, this should not undermine the importance of students providing their own contribution.

This raises the *third* question: If Arduino is used in embedded systems education, how can one guarantee that students will provide enough contribution in their projects? One approach requires the submission of a pre-project documentation citing similar existing projects, if any, and providing details of the students' own contributions [12, 15]. This document is reviewed by the instructor, modified if necessary, and finally approved before the students can start working on their projects. This is an essential step as with the available Arduino resources, there is a great probability that any proposed project will be at least partially available on some forum or website. Never the less, this should not be viewed as a complete disadvantage as it was shown in [55] that online forums are supportive means for engineering students looking to expand their knowledge and make connections to other students outside the classroom.

5 Conclusions

In this paper, the subject of embedded systems education was revisited with the introduction of Arduino. The paper surveyed embedded education challenges recently identified in the literature. Moreover, the paper covered previous works integrating Arduino in embedded systems courses.

It was found that Arduino proved to be a very promising educational platform in embedded engineering. It can be utilized to cover a lot of the core units under the embedded systems knowledge area in the 2016 model curriculum for computer engineering. In addition, it can be used to overcome a number of challenges facing embedded education nowadays.

Although Arduino has a clear promise, it cannot be stated with certainty that it is a suitable platform for embedded education. Hence, a number of research directions were proposed in this work to further examine this subject. One direction is to conduct a research study comparing different microcontroller platforms for higher-level education. Another direction is to develop effective teaching methodologies that guarantee the delivery of the learning outcomes, with the appropriate depth, in the case of using Arduino. More specifically, how to balance low-level vs. high-level knowledge? And how to make sure that students provide considerable contribution in their projects? Furthermore, it remains open to investigate the implementation of Arduino-shields projects and the use of Arduino in covering the topic of embedded operating systems.

6 References

[1] Minaie A. and Sanati-Mehrizy R. (2208). Comparison of Embedded Systems Education in the United States, European, and Far Eastern Countries. In the American Society for Engineering Education Annual Conference, pp. 13.19.1-13.19.6.

[2] Koopman P., Choset H., Gandhi R., Krogh B., Marculescu D., Narasimhan P., Paul J. M., Rajkumar R., Siewiorek D., Smailagic A., Steenkiste P., Thomas D. E., and Wang C. (2005). Undergraduate Embedded System Education at Carnegie Mellon. In ACM Transactions on Embedded Computing Systems, vol. 4, no. 3, pp. 500-528. https://doi.org/10.1145/1086519.1086522

[3] Ibrahim I., Ali R., Zulkefli M., and Elfadil N. (2015). Embedded Systems Pedagogical Issue: Teaching Approaches, Students Readiness, and Design Challenges. In the American Journal of Embedded Systems and Applications, pp. vol. 3, issue 1, pp. 1-10. https://doi.org/10.11648/j.ajesa.20150301.11

[4] Marwedel P. (2005). Towards laying common grounds for embedded system design education. In the ACM SIGBED Review – Special Issue on the First Workshop ion Embedded Systems Education, vol. 2, issue 4, pp. 25-28.

[5] Chandrasekaran S., Stojcevski A., Littlefair G., and Joordens M. (2013). Project-Oriented Design-Based Learning: Aligning Students' Views With Industry Needs. In the International Journal of Engineering Education, vol. 29, no. 5, pp. 1109-1118.

[6] Kastelan I., Teslic N., and Termerinca M. (2016). Challenges in Embedded Engineering Education. In Advances in Intelligent Systems and Computing, vol. 421, pp. 1-27. https://doi.org/10.1007/978-3-319-27540-6_1

[7] MacBride G., Hayward E. L., Hayward G., Spencer E., Ekevall E., Magill J., Bryce A. C., and Stimpson B. (2010). Engineering the Future: Embedding Engineering Permanently Across the School-University Interface. IEEE Transactions on Education, vol. 53, issue 1, pp. 120-127. https://doi.org/10.1109/TE.2009.2025368

[8] Kastelan I., Lopez B. J. R., Artetxe G. E., Pwinski J., Barak M., and Temerinac M. (2014). E2LP: A unified embedded engineering learning platform. Microprocessors and Microsystems, vol. 38, no. 8, pp. 933-946. https://doi.org/10.1016/j.micpro.2014.09.003

[9] Ravel M., Chang M., McDermott M., Morrow M., Teslic N., Katona M., Bapat J. (2009). A Cross-curriculum Open Design Platform Approach to electronic and Computing Systems Education. In the IEEE International Conference on Microelectronic Systems Education (MSE), pp. 69-72.

[10] Bird N. (2011). Use of The Arduino Platform for a Junior-level Undergraduate Microprocessors Course. In the American Society for Engineering Education Annual Conference, pp. 22.1600.1- 22.1600.11.

[11] Jamieson P. (2011). Arduino for Teaching Embedded Systems. Are Computer Scientists and Engineering Educators Missing the Boat? In the International Conference on Frontiers in Education: Computer Science and Computer Engineering (FECS).

[12] Jamieson P. and Herdtner J. (2015). More Missing the Boat - Arduino, Raspberry Pi, and Small Prototyping Boards and Engineering Education Needs Them. In the IEEE Frontiers in Education (FIE), pp. 1442-1447. https://doi.org/10.1109/fie.2015.7344259

[13] Dasig Jr. D. (2014). User Experience of Embedded System Students on Arduino and Field Programmable Gate Array (FPGA). In the Second International Conference in Applied science and Environmental Engineering, pp. 124-128.

[14] Herzog P. and Swart A. (2016). Arduino – Enabling Engineering Students to obtain Academic Success in a Design-based Module. In the IEEE Global Engineering Education Conference (EDUCON), pp. 66-73.

[15] El-Abd M. (2016). How Course Projects can Successfully Prepare Engineering Students for Capstone Design Projects. In the IEEE Global Engineering Education Conference (EDUCON), pp. 746-750. https://doi.org/10.1109/EDUCON.2016.7474635
[16] Patińo O. A., Conterars-Ortiz S., and Martínez-Santos J. C. (2016). Evolution of Microcontroller's Course under the Influence of Arduino. In 14th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Engineering Innovations for Global Sustainability".
[17] Rodriguez-Sanchez M. C., Torrado-Carvajal A., Vaquero J., Borromeo S., and Hernandez-Tamames J. A. An Embedded Systems Course for Engineering Students Using Open-Source Platforms in Wireless Scenarios. IEEE Transactions on Education, doi: 10.1109/TE.2016.2526676 https://doi.org/10.1109/TE.2016.2526676
[18] Santos R. R. (2014). Open Hardware Platforms in a First Course of the Computer Engineering Undergraduate Program. In Frontiers in Education (FIE), pp. 2085-2091.
[19] Al-Busaidi A. (2012). Development of an Educational Environment for Online Control of a Biped Robot using MATLAB and Arduino. In Mechatronics-REM, pp. 337-344. https://doi.org/10.1109/mecatronics.2012.6451030
[20] Cheng H., Hao L., Luo Z., and Wang F. (2016). Establishing the Connection between Control Theory Education and Application: An Arduino Based Rapid Control Prototyping Approach. The Journal of Learning and Teaching, vol. 2, no. 1, pp. 67-72.
[21] Kuwan W-H., Tseng C-H., Chen S., and Wong C-C. (2016). Development of a Computer-Assisted Instrumentation Curriculum for Physics Students: Using LabVIEW and Arduino Platform. The Journal of Science Education and Technology, vol. 25, pp. 427-438. https://doi.org/10.1007/s10956-016-9603-y
[22] Williams W. (2013). LabVIEW and Arduino as a gateway to PLC programming. In the American Society for Engineering Education Annual Conference, pp. 23.846.1-23.846.12.
[23] D. Cãlinoiu, R. Ionel, M. Lascu, and A. Cioablã. (2014). Arduino and LabVIEW in Educational Remote Monitoring Applications. In the IEEE Frontiers in Education (FIE), pp. 245-249.
[24] Georgitzikis V., Akribopoulos O., and Chatzigiannakis I. (2012). Controlling Physical Objects via the Internet using the Arduino Platform over 802.15.4 Networks. IEEE Latin America Transactions, vol. 10, no. 3, pp. 1686-1689. https://doi.org/10.1109/TLA.2012.6222571
[25] Mullet G. (2016). Teaching the Internet of Things (IoT) Using Universally Available Raspberry Pi and Arduino Platforms. In the American Society for Engineering Education Annual Conference. https://doi.org/10.18260/p.26053
[26] Dobrilovic D. and Zeljko S. (2016). Design of Open-Source Platform for Introducing Internet of Things in University Curricula. In the 11th IEEE International Symposium on Applied Computational Intelligence and Informatics (SACI), pp. 273-276.
[27] Pritchard J. and Mina M. (2013). Modern Embedded Systems as a Platform for Problem Solving in Freshman Engineering: What is the Best Option? In the American Society for Engineering Education Annual Conference, pp. 23.911.1-23.911.12.
[28] Recktenwald G. and Hall D. (2011). Using Arduino as a Platform for Programming, Design, and Measurement in a Freshman Engineering Course. In the American Society for Engineering Education Annual Conference, pp. 22.1609.1-22.1609.23.
[29] Vasquez H. and Fuentes A. (2013). Integration of Sensors and Low-Cost Microcontrollers into the Undergraduate Mechanical Engineering Design Sequence. In the American Society for Engineering Education Annual Conference, pp. 23.789.1-23.789.13.
[30] Tian J. (2014). A Design Approach in an Introduction to Engineering Course. In the American Society for Engineering Education Annual Conference, pp. 24.44.1-24.44.12.

[31] Orr M. K., Swafford C., Hahler S., and Hall D. (2104). Factors that influence confidence: Untangling the influences of gender, achievement, and hands-on activities. In the IEEE Frontiers in Education (FIE), pp. 2580-2584.
[32] Berry C., Chang D., and Miller C. (2016). From LEGO to Arduino: Enhancement of ECE Freshman Design with Practical Applications. In the American Society for Engineering Education. https://doi.org/10.18260/p.26972
[33] Wu N. and Zeng K. (2016). Embedded System Based First-Year Engineering Course with Aid of Online Simulation and Social Media. In the 9th First Year Engineering Experience (FYEE) Conference.
[34] Butterfield A. and Branch J. (2015). Results & Lessons Learned from a Chemical Engineering Freshman Design Laboratory. In the American Society for Engineering Education Annual Conference, pp. 26.1337.126.1337.25.
[35] Kubinova S. and Slger J. (2015). ChemDuino – Low cost chemical measurements for use in lecture and laboratory. In the Journal of Chemical Education, vol. 92, issue 10, pp. 1751-1753. https://doi.org/10.1021/ed5008102
[36] Zachriadou K. and Yiasemides K. (2012). A low-cost computer-controlled Arduino-based educational laboratory system for teaching the fundamentals of photovoltaic cells. In the European Journal of Physics, vol. 33, pp. 1599-1610. https://doi.org/10.1088/0143-0807/33/6/1599
[37] Huang P. (2015). Open-source Hardware – Microcontrollers and Physics Education – Integrating DIY Sensors and Data Acquisition with Arduino. In the American Society for Engineering Education Annual Conference, pp. 26.1205.1-26.1205.13.
[38] Haugen A. and Moore N. A model for including Arduino microcontroller programming in the introductory physics lab. arXiv:1407.7613v1 [physics.ed-ph].
[39] Kendre S. S., Mulmule P. V., and Shirbahadurkar S. D. (2013). Developing Experimental Platforms Using Common Software Tools For Enhancing Technical Skills of Electronics Engineering Students in Microcontrollers. In the IEEE Frontiers in Education (FIE), pp. 1450-1452. https://doi.org/10.1109/fie.2013.6685072
[40] Onime C., Uhomoibhi J., and Zennaro M. (2014). A Low Cost Implementation of an Existing Hands-on Laboratory Experiment in Electronic Engineering. In the International Journal of Engineering Pedagogy (iJEP), vol. 4, issue 4, pp. 4-7. https://doi.org/10.3991/ijep.v4i4.3707
[41] Yoder R. B. (2015). An Arduino-Based Alternative to the Traditional Electronics Laboratory. In the Conference on Laboratory Instruction Beyond the First Year (BFY), pp. 107-110. https://doi.org/10.1119/bfy.2015.pr.027
[42] Sobota J., Pisl R., Balda P., and Schlegel M. (2013). Raspberry Pi and Arduino Boards in Control Education. In the 10th IFAC Symposium Advances in Control Education, pp. 7-12. https://doi.org/10.3182/20130828-3-uk-2039.00003
[43] Candela F. A., Garcia G. J., Puente S., Pomares J., Jara C. A., Perez J., Mira D., and Torres F. (2015). Experiences on using Arduino for laboratory experiments of Automatic Control and Robotics. In The International Federation of automatic Control (IFAC), pp. 105-110. https://doi.org/10.1016/j.ifacol.2015.11.221
[44] Albayrak A., Albayrak M., and Bayir R. (2015). Design of Matlab/Simulink Based Development Board for Fuzzy Logic Education. In the IEEE International Conference on Fuzzy Systems, pp. 1-7.
[45] Esposito W. J., Mujica F. A., Garcia D. G., and Kovacs G. T. A. (2015). The Lab-In-A-Box project: An Arduino compatible signals and electronics teaching system. In the IEEE Signal Processing and Signal Processing Education Workshop (SP/SPE). https://doi.org/10.1109/DSP-SPE.2015.7369570

[46] Hill L. and Ciccarelli S. (2013). Using a Low-Cost Open Source Hardware Development Platform in Teaching Young Students Programming Skills. In the 14th Annual ACM SIGITE Conference on Information Technology Education, pp. 63-68. https://doi.org/10.1145/2512276.2512289
[47] Tenra K. (2014). Practice of the Programming Education using Arduino and the Class Support System. In the 22nd International Conference on Computers in Education (ICCE), pp. 969-974.
[48] Bojic I. and Arratia J. F. (2015). Teaching K-12 Students STEM-C Related Topics through Playing and Conducting Research. In the IEEE Frontiers in Education (FIE), pp. 548-555. https://doi.org/10.1109/fie.2015.7344109
[49] Tsukamoto H., Takemura Y., Nagumo H., Ikeda I., Monden A., and Matsumoto K-I. (2015). Programming Education for Primary Schoolchildren Using a Textual Programming Language. In the IEEE Frontiers in Education (FIE), pp. 1008-1014.
[50] Herger L. M. and Bodarky M. (2015). Engaging Students with Open Source Technologies and Arduino. In the IEEE Integrated STEM Education Conference (ISEC), pp. 1-7. https://doi.org/10.1109/isecon.2015.7119938
[51] Carnegie D. and Watterson C. (2013). Issues of Recruitment and Retention for a New Engineering Provider. In the IEEE Frontiers in Education (FIE), pp. 665-671.
[52] Fotopoulos V., Spiliopoulos A. I., and Fanariotis A. (2013). Preparing a remote conducted course for microcontrollers based on Arduino. In The 7th International Conference in Open and Distance Learning, pp. 133-139.
[53] Thornton M. A., Manikas T. W., and Laplante P. A. (2013). Embedded and Real-time Systems Classes in Traditional and Distance Education Format. In Frontiers in Education (FIE), pp. 1379-1385.
[54] Parkhomenko A., Gladkova O., Ivanov E., Sokolyanskii A., and Kurson S. (2015). Development and Application of Remote Laboratory for Embedded Systems Design. In the International Journal of Online Engineering (iJOE), vol. 11, issue 3, pp. 27-31. https://doi.org/10.3991/ijoe.v11i3.4519
[55] Teo H. J., Johri A., and Brogan D. S. (2013). Towards an Understanding of ECE Students' Use of Online Homework Help Forums. In the IEEE Frontiers in Education (FIE), pp. 400-404. https://doi.org/10.1109/fie.2013.6684854

7 Author

Mohammed El-Abd is an Associate Professor of Computer Engineering in the ECE department at the American University of Kuwait (AUK). He is a senior member of IEEE. He has over 15 years of teaching experience with specific interests in embedded systems, micro-processors, micro-controllers, computer architecture, robotics and artificial intelligence.

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Resilient Learning

Towards Integration of Strategic Research Programmes, Higher Education Functions and Regional-National Development

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Rauno Ilmari Pirinen
Laurea University of Applied Sciences, Espoo, Finland
rauno.pirinen@laurea.fi

Abstract—In this study, the concept of Learning by Research and Development (R&D) is furthered to the world of more resilient learning in the setting of security related R&D projects for development of co-creative products, services and action competence. The background of this study includes an interdisciplinary combination of service science, security, computer science, pedagogy, engineering, and management science. The interdisciplinary combination involves researchers, learners, teachers, and other participants connecting and integrating the academic disciplines, professions, and technologies, along with their methods and perspectives for co-creation of a common goal. This goal emphasizes results as high-value impacts, as well as the value of products, services, and innovations as "deliverables" of the integrative learning process. Until recently, the Learning by R&D model is clear and transparent; as such, it can be adopted by learning and R&D integration of other sciences and higher education institutions. The structure of the model is also easy to adapt and renew in case of a change, which means that it can develop from the inside on the one hand, and produce interactions, adaptions, resilience and innovations on the other.

Keywords—adaption, deliverable, integrative learning, resilience, resilient learning, scope, situated learning and participation

1 Introduction

Integration of externally funded and critical national Research and Development (R&D) functions and its results and deliverables for high-value impacts in higher education institution is a complex and interaction-based process, not only within technology, but merged with the economic, legislative, and social environments, where the R&D integration is also influenced by government policy and programmes, financial instruments, laws and regulations, and economic boundary conditions. In this study, the investigation of higher education functions and EU research system is addressed to collective contribution of: 1) knowledge, 2) competence, 3) capability, 4) operative performance, 5) action proficiency, 6) adaptive capability, and 7) resilience.

In higher education institutions, research activities and achieved high-value impacts by adaptive capability and resilience have become globally important for regional-national development [1] and societies due to the requirement of mutability of new competence and competent networking experts to meet and adapt current and future challenges [2] and manners of learning [3].

In this view of integration of higher education, externally funded R&D and regional-national development; Learning by R&D is a pedagogical and collective approach in which learning is linked to applied R&D projects and development culture [4]. This indicates that learning expertise arises from social interaction, reflection, knowledge and competence sharing, researching, and solutions-finding of shared agenda-based R&D objects, such as "learning scopes" and collective adaption and co-creation of R&D "deliverables". The integrative model emphasizes cooperation and creating learning by "research and development path-dependencies" [5] and makes it possible to include and use various scientific perspectives and methods of learning especially for action-related competence and divergent continuums of studies and R&D projects. The genealogy and path-dependency of Learning by R&D concept development is described in followed publications: Research Framework of Integrative Action [6]; Externally Funded Research and Development Projects in Perspective of Learning [4]; and dissertation namely Towards Realization of Research and Development in a University of Applied Sciences [5].

It is frequently impossible to clearly define the work objectives as "R&D related learning scopes" in advance, and they are instead specified throughout the solution-development process. The R&D related learning process requires critical thought strategies and skills for justifying solutions, resilient dimensions and designing of evidence evaluation. Usually, work of R&D consists of a multidisciplinary setting, continuous solution-development process, focusing on research, development, and generating new competence and action related capabilities. The end results as "deliverables" can be, e.g., a creation, an artifact, a new operating method, an improved methodology, a model, an action capability, a service, or a product as evidence, which is achieved by integrating learning and R&D. The most related and reflected literature followed: the new production of knowledge [7]; experiential learning [8]; the critical theory of adult learning [9]; action learning [10]; and learning by expanding as an activity-theoretical approach [11].

One based assumption of study is that realization of regional-national development, R&D, and its leadership-management functions are rather far from a linear-normative process; instead, this political-decision-making setting is shared by the results of dynamic R&D processes that involve interactions between several actors (see Fig.1) and things that no single actor, such as one higher education institution, can achieve or manage alone [12]. However, the integrative model and collective resilient learning perspective can face a high level of uncertainty, unexpected events, and rival implementation models, e.g., "a separation model" where only high performance units and selected scopes are involved in funded R&D and regional-national development within dedicated actors' networks and higher education institutions.

In this study, the term "resilient learning" is related to the increased rate of interactions and external R&D pipelines as more resilient scopes and deliverables for evi-

dence of lessons learnt and catalytic agents in a processes which shares that knowledge and higher education can be preserved as a service, methodology, product, activity, capability, demand of change, required adaption, performance, policy, or as educational, innovative, or intellectual assets which can be exported for a high value and impact returns as in resonance with the utility related Humboldtian university model; the school as a centre of inquiry [13]; metaphors of learning [14]; situated learning [3]; and interaction between learning and development [15].

In the continuum of this study, the terms "integration" and "integrative learning" address an interactive way of learning where an individual learns along with a workplace, institution, school, and R&D community, such as an international research consortium, as well as alongside a learning organization and across borders and disciplinary silos, as in a collective learning space that can be regional or individual-global oriented [6]. In this setting, the term "learner" refers to a student, teacher, researcher, decision-maker, participant, or even artifact such as "an intelligence as system based to Bayesian belief network" which can enrich the learner's own decisions through collaborative R&D by sharing knowledge and expertise and learning from others where R&D collaboration for learning is used. "Student" is used to indicate that a person is registered as a student in the database of the national Ministry of Education and Culture.

The role of term "resilience" in this study is imperative because it can be expected to further our surviving capabilities by related changes on demand and furthering of novel learning designs and curriculums. This learning design as "resilient learning" concept with address what we need to study when faced with inevitable difficulties, such as often scopes described are in national strategic research agenda and H2020 calls: as grounded so far, the emerging concept of "resilient learning" is approached for achievements of surviving capabilities for changes on demand and manners to enhance the capability at all levels of activities to create paths that are robust yet flexible, to monitor and revise risk models, and to use resources proactively in the face of disruptions or pressures of ongoing activities such as learning, control, production, service, trade or industry. Resilience addresses also to an ability to recover from, or building new positions to, misfortune or adaption of mandatory change. The term "resilience" includes typically four abilities: 1) to plan and prepare, 2) absorb disturbance, 3) recover from, and 4) adapt to known or unknown threats. In this study, the empirical and multidisciplinary R&D results point to the rather practical basis of the term "resilience" and necessitate revisions of its theory, related to such as described in [16] and genealogies of resilience [17].

In the operative environment of this study, higher education institutions are traditionally focused as contributors of new knowledge [18] and competence-professional development [1]. Humboldtian model of higher education and high value returns is addressed in the following studies: development of services [5]; technology and policy [12]; co-creation as manner [19]; value-building [20]; high-value economic returns and cooperation [21]; systemic utility production [22]; path-dependency [23]; and living-labs [24]. In this study, expected new advances are taking place regarding co-operation in emergent value networks (see Fig.1), co-created innovation, the contribution of pioneering innovations, and regional development affecting social and global

development. The term "co-creativity" is understood as collaboration and described as the "secret to breakthrough creativity" [19]. Learning is placed in collaboration with innovation systems and living-labs [24]. A last-mile research approach for general utility production in the end addresses the value-building and economic returns on a national-global scale [22]. An integrative learning space and examples of the use of the research methodology as continuums of the integrated R&D related learning in the context of international safety and security R&D projects as described in [5].

The original foundation of higher education and its various ways of learning has a long tradition. For example, a strong resonance for this operational capability and resilient learning and training theme can be found far behind Dewey's *Democracy and Education*, where he said, "Education is not an affair of telling and being told, but an active and constructive process … Its enactment into practice requires that the school environment be equipped with agencies for doing, with tools and physical materials, to an extent rarely attained. It requires that methods of instruction and administration be modified to allow and to secure direct and continuous occupations with things" [25] [p.33]. Dewey explained learning from the perspective of passive absorption to learning by doing; here, this "doing" is R&D-related and learning by more resilient direct contact with things as well as learning through real-life contexts, inquiry, simulations, and training for an adaptive reasoning and action competence. Dewey's classical educational theories and models had large-scale influence on later views of learning. Almost none of the reviewed learning approaches in this study is thought to be totally new, but rather is seen as paths and mind resonance with Dewey, such key literature as: pedagogic creed [26] and the theory of inquiry [27].

2 Methodology

In this study, the multiple case study approach was used, and the research setting of the study addresses the following literature: "the case research strategy in studies of information systems" [28]; "building theories from case study research" [29]; "case studies and theory development in the social sciences" [30]; "qualitative data analysis" [31]; "real world research" [32]; and "case study research design and methods" [33]. In this analysis, the multiple case studies followed replication logic, and the selected cases served in a manner similar to multiple experiments, with similar results. A literal replication or contrasting results in a theoretical replication predicted explicitly at the outset of the investigation. The case study analysis used herein brings an understanding of a complex issue and object, and can extend experience or add strength to what is already known through previous research and reviewed literature. Here, case studies emphasize a detailed contextual analysis of a limited number of events or conditions and their relationships when the relevant behaviour is not manipulated and the role of the researcher is that of an "objective outsider," as [34] positioned.

Reference [33] noted that the simplest multiple-case design would involve the selection of two or more cases that are believed to be literal replications, while a more complicated multiple-case design would result from more and different types of new

theoretical replications, such as *the theoretical aspects of learning paths by scopes, deliverables and resilience* represents, as according to [30] earlier [29] guidance for theory building. In this study, the end of data collection and analysis was indicated by saturation, when no new information emerged for the research purpose [35].

The data collection of this study is cumulative and systematically used for a qualitative analysis, where (n) indicates an instance of data collection used for this analysis between January 2008 and March 2017. The data collection is comprised according to the results descriptions by Finnish Academia including eighteen (n=18) cumulative categories: 1) scientific publication (n=52) according to publication forum classification; 2) number of open data collections (n=3) facilitated and licensed data collections used; 3) collective creation of international publication (n=72) articles; 4) data of international researcher exchange; 5) integration of education (n=6) study units related (n=3) theses and (n=3) dissertations; 6) data of European Commission's funded research projects (n=4) in FP7 & H2020, data of national funded strategic research projects (n=1) and data of new applications for H2020 funding (involved cases descried more detailed in next chapter); 7) presentations and audiences with (n=56) stakeholders; 8) data of (n=4) workshops and (n=6) seminars, creation of (n=4) events for research and development; 9) participation to public audiences, such as in a parliament and participation to statements (n=1); 10) publication in (n=6) newspapers and general descriptions according to publication forum classifications; 11) invited (n=3) presentations; 12) indicators of social media: Twitter, LinkedIn, Facebook and (n=3) homepages; 13) support of public events for international, national, and regional audiences; and data of economic indicators, such as 14) investigations, 15) patents, 16) licenses, 17) spin-offs, and 18) start-ups.

3 Description of Cases

The data collection category namely R&D projects for qualitative analysis included followed: the two TEKES funded R&D projects (n=2), namely RIESCA and SATERISK; the four (n=4) security-related European Commission FP7 or Horizon funded R&D projects, namely PERSEUS, ABC4EU, EU_CISE_2020 and MARISA; and the data gathering of Academy of Finland Strategic Research Council's Programme's Security in a Networked World project (n=1), namely From Failand to Winland, communicated on Twitter as #WINLandFI.

RIESCA: Rescuing of Intelligence and Electronic Security Core Applications [Funded by TEKES: October, 2007 to March, 2010] was the first of our externally funded R&D projects. The research of RIESCA addresses a number of systems, such as transport and logistics, power and telecommunication, hydropower and nuclear power stations, which are critical to the day-to-day functioning of any technologically advanced society, such as Finland. When assessing possible risks, it is only seldom taken into account that power, hydropower and nuclear power plants are critically dependent on the reliability and security of information systems. The aim of RIESCA was to offer contributive and constructive solutions, such as design-based solutions, to this problem. The student-centered R&D and novel resilience viewpoint was integrat-

ed in RIESCA: an individual student or larger student groups were assigned to defined parts of the project. There are two notable advantages conferred by the use of students on the project, namely: 1) confidential information management can be used and developed in study units and; 2) the students acquire more new professional expertise that fits with the principles of R&D framework. In view of collaboration, the trust-based networked expertise relationships were achieved in RIESCA.

SATERISK: Risks of Satellites and Satellite Tracking System [Funded by TEKES]. The idea to study risks related to satellites was created by students of Laurea in 2008. Funding from TEKES was secured on 14.11.2008 and allocated for the period 1.9.2008 to 31.8.2011. The goal of SATERISK was to study the risks connected to satellite tracking and to ascertain if the use of satellite tracking can generate further risks. The project analyses risks using different approaches: legal, technical and mode of use; it will also study potential future requirements and risks. SATERISK has expanded into an academic multi-disciplinary collaboration with the University of Lapland, ITMO in St. Petersburg, Russia and the BORDERS network, coordinated by the University of Arizona, USA. Here it is noteworthy that SATERISK inspired students' resilient scope thinking and gave the possibility for something else to emerge; SATERISK temporarily moved students' minds far away from daily official routines and responsibilities. This clearly advanced the aspects of motivation. SATERISK also demonstrated that a student's expertise itself and student-workplace relations can trigger externally funded R&D projects.

PERSEUS: Protection of European Borders and Seas through the Intelligent Use of Surveillance [Project ID 261748; Funded under FP7-SECURITY] was coordinated by INDRA Sistemas with n=29 partners. The timeframe of the PERSEUS research was between January 2011 and December 2014. In this study, the selection of PERSEUS as a case represents a program and research consortium that aims at the large-scale integration, validation, and demonstration of novel systems and symbolizes European research collaboration, providing a federative frame to join research and steering in areas of significant European interest. In this study, the focus of the PERSEUS investigation was in resilience and adaption of consortium functions and research on international knowledge transition and path-dependency mechanisms, dissemination, and events.

ABC4EU: Automated Border Control Gates for Europe [Project ID 312797; Funded under FP7-SECURITY] is a European Union wide R&D project and involves a Consortium of 15 partners from 8 different countries. The purpose is to make border control more flexible by enhancing the workflow and harmonizing the functionalities of automated border control gates. The project started in January 2014 and will last for 42 months. It is led by INDRA Sistemas S.A. from Spain. In recent years, many ABC Gates have been deployed in the main European airports, most of them as pilot projects intended to test their capability to improve the border crossing processes in aspects such as speed, security, automation, and false rejection reduction. In particular, resilience management and harmonization would be required in areas as e-passports management, biometrics, gate design, human interface, parallel processes, signalling, and interoperability.

EU_CISE_2020: European Union's Information Sharing Environment [Project ID 608385; Funded under FP7-SECURITY] addresses steps forward along the accomplishment of the European roadmap for Common Information Sharing and Distributed Systems and Services Environment. The project attains the widest possible experimental environment of innovative and collaborative services and processes between European maritime institutions and takes as reference a broad spectrum of factors in the field of European Integrated Maritime Surveillance, arising from the European legal framework, as well as from studies, pilots, and related R&D projects. The timeframe of EU_CISE_2020 is between 01/06/2014 and 01/06/2018.

MARISA: Maritime Integrated Surveillance Awareness [Project ID 740698; Funded under H2020] is new H2020 project, timeframe between April 2017 and September 2019. The overarching goal of this project is to provide the security communities operating at sea with a data fusion toolkit, which provides a suite of methods, techniques and software modules to correlate and fuse various heterogeneous and homogeneous data and information from different sources, including Internet and social networks, with the aim to improve information exchange, situational awareness, decision-making, reaction capabilities and resilience. The expected solution will provide mechanisms to get insights from any big data source, perform analysis of a variety of data based on geographical and spatial representation, use techniques to search for typical and new patterns that identify possible connections between events, explore predictive analysis models to represent the effect of relationships of observed object at sea. Enterprise and ad-hoc reporting and Maritime Services, within the CISE context, will be provided to support users and operational systems in their daily activities, as well as presentation tools for navigating and visualizing results of data fusion processing.

#WINLandFI: From Failand to Winland, the Academy of Finland Strategic Research Council [Funding ID 303623; from April 2016 to March 2019] as ongoing Critical Research Project. This research project will take you from Failand (failed future Finland) to Winland, e.g., Finland where key security threats have been responded to with resilient policy-making. The starting point of research is the question, "What kinds of security risks and threats could paralyse Finland so fundamentally that our country becomes Failand?" The proposal included arguments that Failand becomes reality if two of the most fundamental elements of a functioning society fail: food security and energy security, which both are closely linked to water security. In addition, the proposal surmises that such failure is likely to result from the sum of three key components: long-term pressures, shocks and surprises, and policy responses. Addressing such an equation, and guiding the way to Winland, requires a multidisciplinary team that works together in an inter- and transdisciplinary manner, involving the key stakeholders throughout the process. #WINLandFI consortium have paid focused attention to establish an integrative research and stakeholder process that will utilise a combination of scenario planning and decision analysis, supported by a series of co-creation workshops and other interaction methods. With the help of these scenarios; #WINLandFI consortia will study how water, food, and energy-related pressures, shocks and surprises, and policy responses affect Finland's overall security.

4 Research Findings

Focusing on regional and national development and R&D is a significant purpose for all higher education institutions in Finland. In the past few years, the structural reform of higher education in Finland is represented, and this reform has been widely and actively discussed nationally in order to develop the national and regional innovation system and to clarify the shared nature of the higher education system. This produces new, collaborative knowledge and competence and searches for creative solutions for focused problems and challenges at various levels and project continuums. The importance of R&D integration is clearly emphasised when combining regional competence, participating in networks, and utilising different partnerships in shared R&D processes. The functions of R&D at all higher education institutions can be reasoned by a purposeful and experiential approach, as producing expertise in processes of knowledge transfers, transformations, and catalyses related resilient learning aspects.

The term "high-value impact" addresses the amount of realized economic and social value as well as achieved value and impact returns, which are created by applying knowledge generated by a research consortia and R&D collaboration. The study revealed that the terms "value", and achieving "high-value impacts", are in line with the concept of value concentration where values are related to knowledge and where they produce outcomes described as revised concept of value concentration. The concentration quartet includes the following: 1) academic value as intellectual property, 2) value of research, 3) value of education, and 4) empiric value, (described later in Fig.1). Here, the term "empiric value" addresses value returns by disseminated artifacts, services, and value concentrations for competitiveness-business and policy development related reasoning.

One micro-level purpose and contribution of this study addresses the form and development of higher education that focuses on the demands of the individual-national-global comprehensive security domain. Here, teachers, policy, and authority representatives work and interact more closely together as a collective learning community that involves students (legitimate peripheral participation) and the implementation of study units in higher education and shared R&D. This shared R&D includes learning by national-international research consortiums and work packages as realizations, such as in manners of catalytic and adaptive acquisition, participation and co-creation, e.g., manners of R&D and more resilient learning for building something new: resonance with towards realization of research and development [5] and creating entrepreneurial universities [1].

Furthermore, this study contributes to the understanding and mind of the resilient learning in the view of term "scope", such as "research-learning scope", which can be useful for interactions of an "resilient-elastic nature" and for focusing on the meaningfulness of learning integration, learning paths, and creativity, especially in the perspective of a student's integration into R&D and regional-national development.

The study recorded first that the terms "scope" and "resilient steering" (see Fig.1) were useful to a satisfaction, atmosphere, mutual trust, confidence, and "learning to like or dislike" in a learning space (such as integrated consortia environment) where a

student takes "a scope" and makes his own personal activity, creation, improvement, and validation into the selected or shared learning target as "shared scope", e.g., as in a new application building process, which resulted from scope-based thinking. Second, a "scope" was not loaded by a teacher's knowledge in the beginning of studies, so scope-related knowledge can be composed openly by a student's viewpoints as by resilient-elastic nature, interests, aspiration, and motivation, not necessary only in teacher's or problem-based viewpoints. Third, the term "research-learning scope" can refer to a mental or physical target or subject matter that something deals with in learning. Fourth, the aim of using the "resilient-elastic scopes" in the beginning of R&D related learning integration as frame to support a student's imagination and creativity in learning, and the assumption was that the understanding of resilience relations and "resilient-elastic nature of scope" would generate and maintain the motivation and spirit for learning, balancing the judgments and potentials of objectives, goals, and targets; e.g., the tuning of a cognitive load in a lifetime of studies would be balanced by students and teachers by "alignment and adjusting of scopes". Fifth, the "scope" addresses the idea that, between two people, there is third dimension as "a scope", e.g., a model, artifact, tool, concept, or mental or social factor with which students may share, transfer, adapt, and build knowledge. It communicates, activates, and motivates their personal or team learning spirit and confidence. Sixth, "the scope" increases resilience, "everything does not go as designed" and elasticity in solution based learning approach, both can be approached in the reactive and proactive sense. And lastly, "the design of scopes" bridges "learning by novel research agenda" and "motivation of learners" in the first place and builds furthered components for continuums of using new proposed knowledge sources as with theory and metaphors of learning in action-related competences.

It is noteworthy that new and small enterprises, particularly knowledge-intensive ones, are involved as legitimated actors [3] in the innovation system. In this view, higher education institutions are seen as significant producers of new knowledge and competences, and users of the latest findings and bodies of knowledge in action, which gives them a role within the thematic center as collectors of the innovation system (see Fig.1). Their thematic nature comes from their operative action and resilience as capability in combining knowledge from several sources, such as lead innovation systems, or institutions such as strategic centers of excellence in science, technology, and systemic innovations. In addition, multiple helix cooperation [21] ensures a body of knowledge is co-created with other organizations to contribute to innovations in industry and society as a whole, e.g., national strategic research agenda.

The central challenges faced by the realization of the shared R&D functions and resilience viewpoints in higher education consisted of the following: 1) the establishment of new management forms and culture and control of the mass of projects through the R&D realizations and by higher education institutions, with mutual trust and confidence; 2) the balancing and modularizing of the cognitive load and the challenges of learning in R&D realizations; 3) pedagogical development and continuous, relatively adaptive-resilient change in R&D that pose great challenges for teachers and management; 4) understanding of the meaning of student-centred R&D in communities of work and workplaces as research for work (see relevance to work in

Fig.1); 5) ethics management and issues; 6) the development of incipient internationalization and individual-global interactions; 7) the measurement of the effects and development of utility, usability, and strategic measurement as an evaluation design structure in higher education; and 8) dissemination of the new R&D-related learning model and ethic for sustainability manners in the context higher education and helix integration.

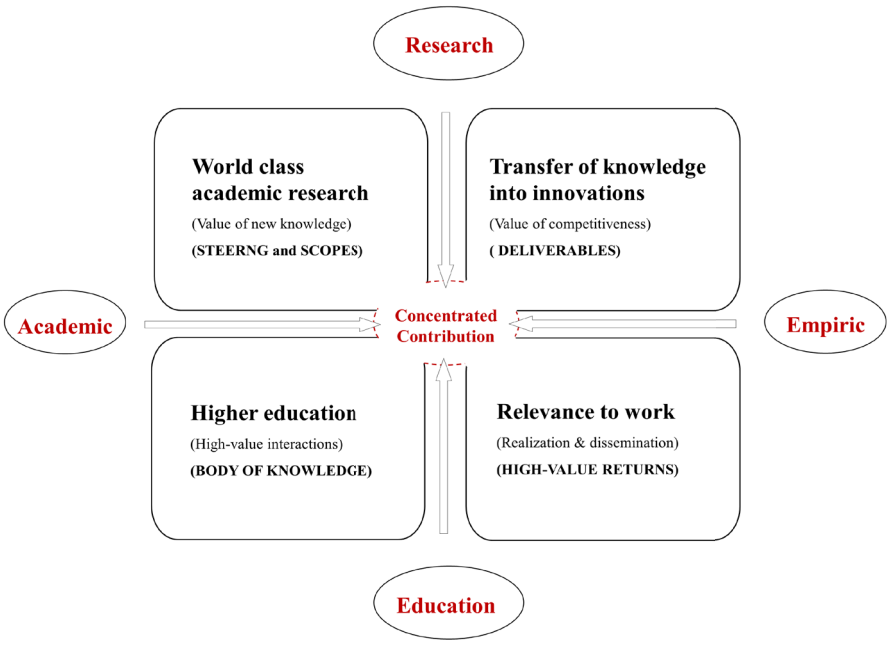

Fig. 1. The revised concept of value concentration (Pirinen, 2013 p.70).

In the perspective of security management-related higher education, a regional-national capacity to provide security-related knowledge-competence-capability pathways and knowledge interconnections depends on the ability to continuously innovate in order to ensure technological leadership and be a credible networking partner for concentrated contribution. The study revealed that resilience related research is necessary in future studies. Hence, current and emergent challenges can be remarked such as the recent dramatic falls in investment in R&D and risk management undermining efforts to support the security and sector, broader defence, and security goals. In this security view, one piece of advice for future study is that creativity and innovative learning scopes should be more systematically designed and adopted for research, development, and innovation activities in the context of current knowledge, competence, capability, and performance (action competence) settings. Hence, the creativity and innovation approach steers R&D process planning towards increasingly participatory, dynamic, and creative forums of new competence production and will enhance learning and resilience.

The comprehensive security-related R&D integration as concept of value concentration (described in Fig.1) has a high value impact on pedagogy, which is delivered

in students' knowledge, competence, and capability building processes. The crucial factors as deliverables are not only subject-specific competence, but also a research-oriented developmental approach, interaction skills, the ability to encounter colleagues, students, and partners dialogically, and having the pedagogical, participation and leadership competence. The qualities of an expert in deliverables promote the implementation of good, high-quality teaching, and foster students motivation, participation, and dignity. From the students' points of view, the emphasis is on motivation, spirit, dignity, guidance, learning process, mutual reflection, professional and human growth, and a research-oriented, developmental approach to own and organization work.

5 Discussion and Remarks

The comprehensive security-related education and new pedagogical solutions have possibilities to further current R&D activities in ways that bring creativity and innovation-building related knowledge towards competence-capability, as well as sustains performance (resilience and competence). The academia-consortium and external funding structures of research activities already exist, as investigated here. However, the comprehensive security integration does need more action competence and capability-related understanding, followed by future studies.

There are many reasons for future progress and discussion of the term "resilience", such as: the number of systems, interconnections, and transaction elements increases over time; the system complexity increases and the resulting interactions become challenging to maintain, e.g., the number of updates, difficulties in using and facilitation, life cycles, continuity management, and for understanding emergent relations between the terms "resilience", "elastic", "robustness", "complexity", and "persistence". In this context, the term "resilience" would be first related to the term "robustness". In this setting, as previously mentioned, the term "robustness" addresses "the degree to which a system is able to withstand an unexpected internal or external event or change without degradation of in system's performance." Then, the term "robustness" indicates "the degree to which system operates correctly in the presence of exceptional conditions." On the other hand, "resilience" refers to the system's ability to recover, retrieve, restore, or regenerate its performance after unexpected impact that declined its performance, as [36] proposes.

In this context, as understood so far, the significance of the term "resilience" addresses the ability of a system, community, or society exposed to security-related threats to resist, absorb, accommodate, and recover from the effects of a threat in a timely and efficient manner, including through the preservation, restoration, and adaption of its essential basic structures and functions to state that it is possible to going on and continuity. Regardless, the term "resilience" includes strong relations to reactive nature in included R&D cases and literatures, e.g., respond, recover, retrieve, restore, and adapt. Our furthered research-learning-scope includes many proactive dimensions, such as "prepare, prevent, configure, and protect". Currently in #WINLandFI, there are ongoing discussions of resilience and stability of ecological systems [16],

community and mechanisms of critical and resilient digital services [37], resilience in globalization and transitional pathways [38], genealogies of resilience [17], from systems ecology to the political economy of crisis adaptation and management and resilient systems [39], and resilience engineering [40].

The relation between the terms "learning scope" and "resilience" in this study was imperative because it can be expected to further our surviving capabilities by related changes on demand and furthering of novel learning designs and curriculums. This resilient learning design with address what we need to study when faced with inevitable difficulties, such as often scopes described in national research agenda and H2020 calls: as grounded so far, the emerging term "resilience" is approached for achievements of surviving capabilities for changes on demand and manners to enhance the capability at all levels of activities to create paths that are robust yet flexible, to monitor and revise risk models, and to use resources proactively in the face of disruptions or pressures of ongoing activities such as learning, control, production, service, trade or industry. Resilience addresses also to an ability to recover from, or building new positions to, misfortune or adaption of mandatory change. The term "resilience" includes typically four abilities: 1) to plan and prepare, 2) absorb disturbance, 3) recover from, and 4) adapt to known or unknown threats. In this study, the empirical and multidisciplinary R&D results point to the rather practical basis of the term "resilience" and necessitate revisions of its theory, related to such as described in [16] and genealogies of resilience [17].

RESILIENCE OF KNOWLEDGE ECONOMY: The discussion of a "knowledge economy" can be addressed here the use of knowledge-intensive technologies and services, such as: information sharing; knowledge sources, knowledge co-creation, and knowledge management to produce information-intensive economic benefits as well as new workplace creation integrated into R&D-related themes. In macro scale, the global economy is transitioning to a "knowledge economy" or "resilient knowledge economy"; in micro scale, higher education is transitioning to a "knowledge economy of more resilient information-intensive services, products, artifacts, policy developments, and methodologies which are achieved in R&D related regional-global collaboration" [5] as well as transitions between knowledge acquisition, participation, and knowledge building and co-creation more resilient learning metaphors.

TOWARDS REASONING OF RESILIENT LEARNING: During the security systems evolution, while each of the systems for digitalization and integration may formally go through the development process, such as readiness requirements, the overall integration analysis, development, and corresponding requirements are clearly increasing due to the following elements which are ever more present: 1) operational and managerial independence of operations; 2) commercial value of data and data fusion; 3) challenges of border and cultural traits; 4) emergent strategies and behaviour; 5) trust building, e.g., over borders and between authorities and vary silos; 6) ethics management and social aspects, e.g., citizen's responsibility and organization's mutual and national responsibility; and 7) path-dependency in evolutionary, developmental, and cultural views.

TOWARDS RESILIENT LEARNING: The study exposed that the terms "scope", "motivated steering", "social characters of involvement" were useful to a satisfaction, atmosphere, mutual trust, confidence, and "learning to like or dislike" in a resilient learning space in such as integrated R&D consortiums where; a student can take "a scope" and makes his own personal activity, creation, improvement, and validation into the selected or shared learning target as "shared scope", e.g., as in a new application-proposal building or co-creation process, which resulted from scope-participation-based thinking.

TRIGGER OF RESILIENT LEARNING: A scope and thematic setting of study triggers (steering) drivers was not loaded by a teacher's knowledge in the beginning of studies, so scope-related knowledge can be composed openly by a student's viewpoints as by resilient-elastic nature, interests, aspiration, and motivation, not necessary only in teacher's or problem-based viewpoints.

TARGET AND SUBJECT ORIENTATION: The term "research-learning scope" can refer to a mental or physical target or subject matter that something deals with in resilient learning. The target of using the "resilient-elastic scopes" in the beginning of R&D related learning integration as frame to support a student's imagination and creativity in learning, and the assumption was that the understanding of resilience relations and "resilient-elastic nature of scope" would generate and maintain the motivation and spirit for learning, balancing the judgments and potentials of objectives, goals, and targets; e.g., the tuning of a cognitive load in a lifetime of studies would be balanced by students and teachers by "alignment and adjusting of scopes and subject matters".

KNOWLEDGE BUILDING ARTIFACTS: The "scope" addresses the idea that, between two people, there is third dimension as "a scope", e.g., a model, artifact, tool, concept, or mental or social factor with which students may share, transfer, adapt, and build knowledge. It communicates, activates, and motivates their personal or team learning spirit, confidence and stimulates peripheral participation.

ENHANCED RESILIENCE: Using the scope as learning trigger-driver increases resilience, "everything does not go as designed" and elasticity in solution based learning approach, both can be approached in the reactive and proactive sense. The design of scopes bridges "learning by novel research agenda" and "motivation of learners" in the first place and builds furthered components for continuums of using new proposed knowledge sources as with theory and metaphors of learning in action-related competences.

TOWARDS SHARED RESILIENT LEARNING IN EUROPE: Collective development forums of European Higher Education Area discusses challenges of higher education institutions and recommends that higher education take on more of a leadership role as actors and pioneers of the innovation system and national-global development progress. According this study, it is evident that higher education institutions, especially in security-related fields, have to be supported by multidisciplinary and transdisciplinary cooperation with business communities and universities, for activation of competence, capabilities, performance, adaptions on demand, and social dialogue.

6 References

[1] B. Clark, Creating Entrepreneurial Universities: Organizational Pathways of Transformation, Bingley: Emerald Group Publishing Limited, 2007.

[2] B. Asheim, "The changing role of learning regions in the globalising knowledge economy, "Regional Studies, vol. 46, pp. 993–1004, 2012. https://doi.org/10.1080/00343404.2011.607805

[3] J. Lave and E. Wenger, Situated learning: Legitimate peripheral participation, Cambridge: University Press, 2009.

[4] R. Pirinen, "Externally Funded Research and Development Projects in Perspective of Learning," International Journal of Engineering Pedagogy, vol. 3, pp. 27–36, 2011. https://doi.org/10.3991/ijep.v1i3.1806

[5] R. Pirinen, Towards realization of research and development in a university of applied Sciences, dissertation, Kuopio: University of Eastern Finland, 2013.

[6] R. Pirinen, "Research framework of integrative action," in Americas Conference on Information Systems, San Francisco, 2009.

[7] M. Gibbons et al., The new production of knowledge, Los Angeles: Sage Publications, 2008.

[8] D. Kolb, "The process of experimental learning," in The process of experimental learning, D. Kolb Ed. New Jersey, Prentice-Hall, 1984, pp. 19–38.

[9] J. Mezirow, "Critical theory of adult learning and education," Adult Education, vol. 32, pp. 3–24, 1981. https://doi.org/10.1177/074171368103200101

[10] R. Revans, The origins and growth of action learning, Bromley: Charwell-Brat, 1982.

[11] Y. Engeström, Learning by expanding: an activity-theoretical approach to developmental research, Helsinki: Orienta-Konsultit Oy, 1987.

[12] V. Harmaakorpi, Building a competitive regional innovation environment: the al development platform method as a tool for regional innovation policy, dissertation, Helsinki: University of Technology: Monikko, 2004.

[13] R. Schaefer, The school as a center of inquiry, New York: Harper and Row Publishing, 1967.

[14] A. Sfard, "On two metaphors of learning and the dangerous of choosing just one," Educational Researcher, vol.27, pp. 4–13, 1998. https://doi.org/10.3102/0013189X027002004

[15] L. S. Vygotsky, "Interaction between learning and development.," in L.S. Vygotsky mind in society, M. Cole et al., Eds. Cambridge, Harvard University Press, 1978, pp. 79–91.

[16] S. Holling, "Resilience and stability of ecological systems," Annual Review of Ecology and Systematics, vol. 4, pp. 1–23, 1973. https://doi.org/10.1146/annurev.es.04.110173.000245

[17] J. Walker and M. Cooper, "Genealogies of resilience: from systems ecology to the political economy of crisis adaptation," Security Dialogue, pp. 143–160, 2011. https://doi.org/10.1177/0967010611399616

[18] M. Scardamalia and C. Bereiter, "Knowledge building: Theory, pedagogy and technology," in Cambridge handbook of the learning sciences, K. Sawyer, Ed. Cambridge: University Press, 2006, pp. 97–118.

[19] R. West, Communities of innovation: Exploring collaborative creativity within a community of graduate instructional designers, dissertation, University of Georgia, 2009.

[20] K. Sawyer, Group genius: The creative power of collaboration, Cambridge: Perseus Books Group, 2008.

[21] H. Etzkowitz et al., Capitalizing knowledge. New Intersections of Industry and Academia, New York: State University of New York Press, 1998.

[22] J. Nunamaker and R. Briggs, ”Toward a broader vision for information systems,” ACM Transactions on Management Information Systems, vol. 2, pp. 1–12, 2011. https://doi.org/10.1145/2070710.2070711
[23] R. Nelson and S. Winter, An evolutionary theory of economic change, Cambridge: Harvard University Press, 1982.
[24] A. Ståhlbröst, Forming future IT: The living lab way of user involvement, dissertation, Luleå: University of Technology, 2008.
[25] J. Dewey, Democracy and Education: An Introduction to the Philosophy of Education, New York: Macmillan, 1916.
[26] J. Dewey, ”My pedagogic creed,” in The essential Dewey: Pragmatism, education, democracy, L. Hickman and T. Alexander, Eds. Bloomington: Indiana University Press, 1897, p. 229–235.
[27] J. Dewey, Logic: The theory of inquiry, New York: Henry Holt and Company, 1938.
[28] D. Benbasat, et al., ”The case research strategy in studies of information systems,” MIS Quarterly, vol 11, pp. 369–386, 1987. https://doi.org/10.2307/248684
[29] K. Eisenhardt, ”Building theories from case study research,” Academy of Management Review, vol. 14, pp. 532–550, 1989.
[30] L. George and A. Bennett, Case studies and theory development in the social sciences, Massachusetts: MIT Press, 2005.
[31] M. Miles and A. Huberman, Qualitative data analysis: an expanded sourcebook, Thousand Oaks: Sage Publications, 1994.
[32] C. Robson, Real world research, Oxford: Blackwell Publishing, 2001.
[33] R. Yin, Case study research design and methods, Thousand Oaks: Sage Publications, 2009.
[34] K. Herr and G. Anderson, The action research dissertation: A guide for students and faculty, Thousand Oaks: Sage Publications, 2005.
[35] J. Corbin and A. Strauss, Basics of qualitative research: techniques and procedures for developing grounded theory, Los Angeles: Sage Publications, 2008.
[36] A. Kott and T. Abdelzaher, ”Resiliency and Robutness of Complex Systems and Networks,” in Adaptive, Dynamic, and Resilient Systems, Boca Raton, Taylor & Francis Group, 2014, pp. 67–85.
[37] R. Pirinen, ”Mechanism of Critical and Resilient Digital Services for Design Theory,” in International Conference on Computer Science, Computer Engineering and Social Media, Lodz, Poland, 2015. https://doi.org/10.1109/cscesm.2015.7331874
[38] G. Wilson, ”Community resilience, globalization, and transitional pathways,” Geoforum, pp. 1218–1231, 2012. https://doi.org/10.1016/j.geoforum.2012.03.008
[39] N. Suri and G. Cabri, Adaptive, Dynamic, and Resilient Systems, Boca Raton: Taylor & Francis, 2014.
[40] N. Atooh-Okine, Resilience Engineering Models and Analysis, New York: Cambridge University Press, 2016. https://doi.org/10.1017/CBO9781139026772

7 Author

Rauno Ilmari Pirinen is with Laurea University of Applied Sciences, Espoo, Finland (rauno.pirinen@laurea.fi).

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Learning Groups in MOOCs

Lessons for Online Learning in Higher Education

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Godfrey Mayende
University of Agder, Norway
godfrey.mayende@uia.no

Andreas Prinz
University of Agder, Norway
andreas.prinz@uia.no

Ghislain Maurice Norbert Isabwe
University of Agder, Norway
maurice.isabwe@uia.no

Paul Birevu Muyinda
Makerere University, Kampala, Uganda
mpbirevu@cees.mak.ac.ug

Abstract—when there is interaction within online learning groups, meaningful learning is achieved. Motivating and sustaining effective student interactions requires planning, coordination and implementation of curriculum, pedagogy and technology. For our aim to understand online learning group processes through identification of effective online learning group mechanisms, comparative analysis was used on a massive open online course (MOOC) run in 2015 and 2016. Qualitative (interaction on the platform) and quantitative (survey) methods were used. The findings revealed several possible ways to improve online learning group processes. This paper concludes that course organization helped in increasing individual participation in the groups. Motivation by peers helped to increase sustainability of interaction in the learning groups. Applying these mechanisms in higher education can help making online learning groups effective.

Keywords—Online Learning, MOOC, Higher Education, Learning Groups, Online Learning Groups.

1 Introduction

The proliferation of ICT in teaching and learning has created new possibilities for supporting collaborative and cooperative learning in distance education [1]. Collaborative learning hinges on the belief that knowledge is socially constructed although

each learner has control over his/her own learning. Vygotsky argues that a person's learning may be enhanced through engagement with others. Learning groups have been preferred for propelling interaction and learning. However, motivating and sustaining effective student interactions are not easy to achieve. That requires planning, coordination and implementation of curriculum, pedagogy and technology [2].

Learning groups have been widely used to enhance learning in higher education and more specifically in distance learning. This is done by giving group assignments to help in the initiation of learning groups. However, challenges of co-locating learners and participation of each group member lead to some learners not contributing on the group assignment. Often, their names are still attached to the work. This causes high failure rates at the end during summative assessment [3], since the learners that do not participate, fail to harness the benefits of the rich learning experiences from group members. Therefore, effective ways of engaging learners online can offer possibilities of enhanced interactions among learners in learning groups.

This study was carried out on a MOOC titled "Success - Unleash Yourself" run by the University of Agder using the NovoEd platform (https://novoed.com/success-agder-2016). The course has been run twice in 2015 and 2016 each from January to March. Our study is aimed at understanding online learning group processes to identify effective online learning group mechanisms. Online Learning groups can help to bring distributed learners together to work. The goal was to establish processes of effective online learning groups in the MOOC. The research questions to be answered are how to form effective learning groups and how to sustain effective online learning group's processes. Further on, we answered the question of how to increase interaction of learners during online learning group process. Interaction is usually encouraged to increase learners' engagement when completing group assignments.

Collaborative learning refers to instructional methods that encourage learners to work together to find a common solution for a given task [4]. Collaborative learning involves effort by groups of learners who are mutually searching for meanings, understanding or solutions through negotiation [2, 5]. Collaborative learning occurs where there are interactions. Anderson in his online learning framework argues that for meaningful learning to happen, there must be high interaction in either student-teacher; student-student and student-content interactions [6]. Mayende, Muyinda [7] and Stahl, Koschmann [2] also asserts that learning takes place through student-student interactions. Ludvigsen and Mørch [8], found out that learners effectively develop deep learning when supported by computer supported collaborative learning. Therefore, a well-structured course to enhance group work can enable student-student interactions in computer supported distance learning [9]. Collaborative learning is based on consensus building through interaction by group members, in contrast to competition. Collaborative activities are essential to encourage information sharing, knowledge acquisition, and skill development [10].

The rest of this paper is organized in four sections. Section 2 presents the approaches and our research methods. In section 3, presents the findings of our work and discussions. Finally, the paper is concluded in section 4.

2 Approaches and methods

This section describes the course design for learning groups and the research methods used. This is described in the following subsections: modules, learning groups, learner support and methods.

2.1 Modules

The course was composed of four modules with specified tasks and activities, paced per course calendar. Learners were expected to complete all modules. The first module takes two weeks to establish the background and to connect the learners. This helps in establishing social connection among learners so that forming learning groups becomes easy. After that there are three modules that last for two weeks each and all of them follow the same basic structure (see table 1 below). The last week is used to wrap up the course and to sketch the way ahead.

Table 1. Basic timeline for a module

Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu
0		1			2	3	4		5	6			7		8		9

Table 1 shows the timelines for a module with the following activities.

- At point "0" the module content and the tasks for the first week are announced.
- At point "1" the first task is reading of the theory presented. This helped the learners to underpin their discussions in the open forums on the module theories.
- At point "2" submission of individual learners answer to the group activity as a starting point. This helped initiating learners into the group activity. Each learner comes into the group with their opinion about the group activity. This helps to increase participation in the learning group.
- At point "3" the reading is concluded with a quiz. This helped to assess the learners on the theories of the module. The quiz is developed in such a way that the learner can attempt the quiz three times. In each attempt the learner is given detailed feedback which enhances more learning about the theories.
- At point "4" tasks for the second week are announced.
- At point "5" the deadline for group hand-in is reached. This hand-in is based on the group's discussion and individual student answer to group task. It is during the group deliberations that the groups agree on final submission and the member who submits.
- At point "6" learners start working on individual hand-in with emphasis on group support. The team members are encouraged to consult their teams when working on the individual activity which is connected to the group activity but contextualized for everyone. Since learners have already worked on the group activity it is easy for the learners to consult one another when working on their individual submission.

- At point "7" soft deadline for individual hand-in.
- At point "8" hard deadline for individual hand-in; peer assessment of individual hand-ins begins.
- Finally, point "9" has the soft deadline for peer assessment of individual hand-ins (hard deadline on Friday that proceeds). The tasks for each week are displayed on top of the platform every time your login. This is an important affordance of the NovoEd tool.

2.2 Learning Groups

In the first module, there were auto-assigned learning groups of around 30 learners each. In the other modules, the learning groups were self-formed and each group had at most 5 members. The activities created for module one was aimed at connecting learners and getting familiar with the platform. This was good in building social connections in learning groups. A juggling activity was used in the first module. Learners were required to learn how to juggle and the submission required them to make video recording when they are juggling. This activity has a game concept which makes learners enjoy and get to know one another with ease. Since the juggling submission is seen by all learners, it helped in enforcing social connection. Activities were designed in such a way that each activity could build on another one within the module. For the activities to enhance group work, learners start with presenting individual answers to group activity. This is then followed by group discussion and hand-in. The learners are then given contextualized individual activity which is built on the previous group activity. Finally, there are at least three peer assessments on individual hand-ins. The final individual activity would be peer assessed using a pre-defined rubric which was developed by the course facilitators. In addition to the peer assessment, each assignment would get more feedback from learners through comments. All the submitted activities are accessed by all the learners in the course with possibility to comment and respond to comment. This encouraged interaction among learners online and learner support.

2.3 Learner Support and Peer Feedback

Learner support is important for online learning courses. Forums were created on the platform to help in giving or receiving feedback from the learners or facilitators. They were created to harness the experiences and knowledge from the community of participants. The learner support ranged from technical to subject matter. This was developed with the aim of allowing feedback to come from the learners themselves given the learner numbers in the MOOC. This fit well with the growing numbers of learners in higher education.

Peer feedback was encouraged since all the submissions were accessed by the learners in the MOOC. This allowed learners opportunity to give peer feedback through comments. Each submission received at least one feedback.

2.4 Differences in the MOOC

Most of the content of the course were the same. However, there was an emphasis on participation in the announcement for the MOOC of 2016. The announcement placed on the platform clearly stated that "this is not a usual MOOC, because it is designed for active learners. You must pay for taking it by putting in at least 10 hours of your time each week. The course features only a few videos, and the learning outcome is achieved by working on the tasks". This is perceived to have played a significant role in improving the course. In this course deadlines were changed from hard to soft. This seemed to have had a good impact on the learner's participation in the course. There was also flexibility on limits of the group size. In the 2015 MOOC, there was fixed limit of five (5) members per group. However, in 2016 MOOC limits of Group size were changed to seven (7) members. This usually happened when learners from the someplace or region wanted to be together in one group.

2.5 Methods

This paper is based on a comparative analysis of the course for 2015 and 2016. Qualitative and quantitative methods were used in collecting data and analysis. This helped in data triangulation. Two course surveys that is mid-term and course-end were run. The surveys contained both open ended and closed ended question. These surveys were responded to by learners on the two MOOC courses. Mid-term survey had 27 respondents for 2015 and 36 respondents for the 2016. Course-end survey had 61 respondents for 2015 and 66 respondents for 2016. Observation was also done on two online learning groups. The interactions on the forums were also used in the analysis. The qualitative data was analyzed by validating the quantitative data collected. This was the done through the themes created from the quantitative results presented.

3 Findings and Discussions

The course design helped learners to engage with course literature. At the end 1.44% of the learners received statements of accomplishment in the 2015 MOOC and 5.04% of the learners received statements of accomplishment in the 2016 MOOC. This is agreement with MOOC completion rates [11-13]. The findings are presented in the following subsections: course organization, do groups reduce structure, what helped with learning, are learning groups working, what did the group help with, and what collaboration tools were used.

3.1 Course Organization

This subsection describes the course organization. The organization determines the success and interactions of the learning group. This agrees with Mayende, Isabwe [9], who established that peer based assessment organization increased interaction and learning among group members. The course organization which puts emphasis on

learning group is shown in figure 1. Initially, the learners within the groups would submit individual work for the group activity. This helps to initiate the learners to the learning group activity and each learner to contribute to the learning group discussion. The points of disagreement from individual viewpoints increased the learners' meaningful learning. An individual submission is open to the entire class to give feedback which helps in the interaction and learning processes.

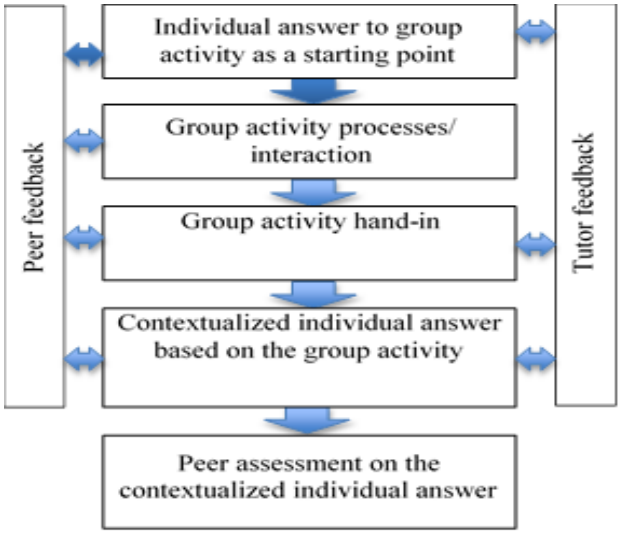

Fig. 1. Course organization

The individual answer to the group activity helps in the learning group discussions/processes. The learners discuss/find solution for group activity online either synchronously or asynchronously. Once the group answer has been arrived at it is submitted/handed-in. However, group hand-in is accessed by all the learners on the MOOC with affordances of peer feedback. The learners are encouraged to give feedback to other group submissions. After submission of the group work, the learners work on the contextualized individual answer which is based on the group activity. The learners are encouraged to consult with group members when working on this individual answer. Then the submission is peer assessed by at least three learners using the rubric developed by the facilitators of the MOOC. This course organization made group formations very easy and encouraged interaction among learners.

3.2 Do Groups reduce structure?

The learners were asked to reveal their perception about the course organization by asking the participants to indicate their levels of agreement to the statements regarding course organization. This was aimed to finding out if groups reduced the course structures. Figure 2 below indicates the percentage agreement with the statements for the MOOC of 2015 and 2016.

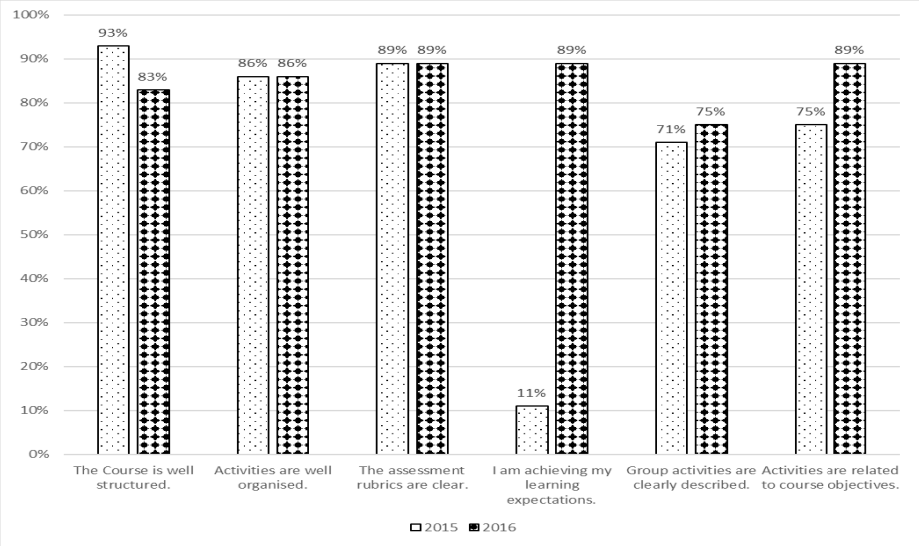

Fig. 2. Do groups reduce structure?

In both MOOCs, the learners perceived the courses to be well structured, activities to be well organized and assessment rubrics to be very clear. This is important in ensuring that online courses in higher education are successful. This is in agreement with our earlier study which indicated that a well-designed detailed course guide can lead to an effective online learning group [14]. The learners also perceived that they achieved their learning expectations in 2016. This could be reason for better completion rate for the course.

In both MOOCs learners agreed that group activities were clearly described with enough time allocation to the activities. This is important for online courses since these types of learners are doing many things in additional to studying. These are typical of distance learners who are working and studying at the same time, which is common for the learners of today. If the group activities are not clearly described this can lead to higher dropout rate especially for the online courses. This can also apply in higher education. It is important for online courses in higher education to ensure that the group activities are clearly described with enough time allocation to the activities. The learners also agreed that the activities were connected to the overall course objective. With activities, which are connected to the course objective, this will help to ensure that the learning outcomes are met.

Generally, learners in both MOOCs agreed that they did not need to be at campus to study this course efficiently. This agrees with already distance learning programmes which are offered at the same competence level. Participants also revealed the importance of forums; 46% believed that forum discussions were essential in the course in 2015 and 69% in 2016; 39% agreed that cafeteria forums helped in getting to know the members of the group in 2015 and 61% in 2016. This indicates that there was more interaction in the forums in 2016 than in 2015 which would be another cause for the better completion rate in 2016.

Therefore, use of learning groups in higher education can reduce online learning course structure. Knowing that online learning groups reduced structure, the next section explores what helped with learning.

3.3 What helped with learning?

Learners revealed that the following teaching resource contributed to learning outcome as shown in figure 3.

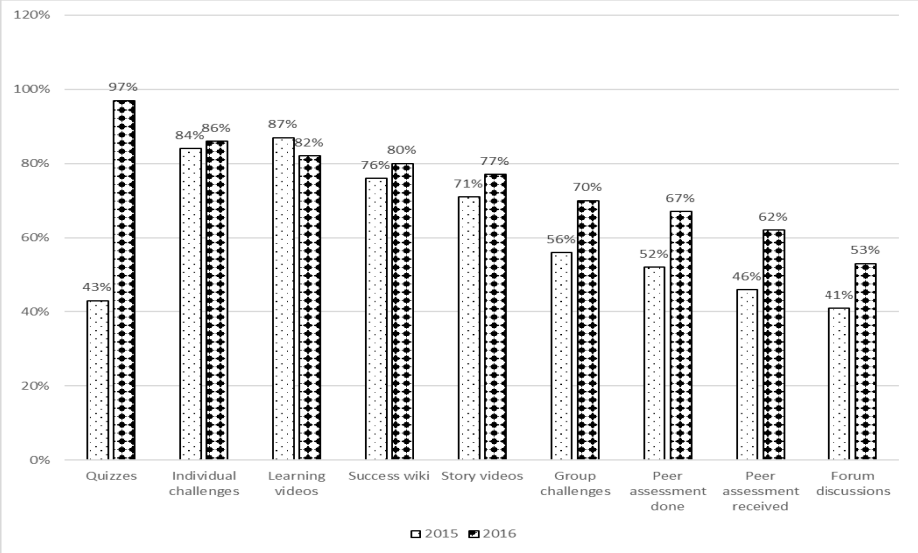

Fig. 3. What helped with learning?

The respondent's perceived quizzes to support learning in the 2016 MOOC. The quizzes were designed with aim of helping learners understand the theories of the course. The quizzes were compulsory and highly dependent on theories of the course. This indicates that the 2016 MOOC benefited more as compared to the 2015 MOOC. This shows that the participants in the 2015 MOOC didn't give enough time to the course literature which was a foundation for the course. Hence the difference in completion differences. The findings also revealed the importance of individual challenges, learning videos, success wiki and story video. Story videos were important because they connected well to the theory by giving authentic examples which helped learners to learn with easy.

The findings reveal differences in group challenges, peer assessment done and peer assessment received with advantage skewed towards the MOOC of 2016. There is need to boost group assignment's contribution so that more completion rates can be achieved. This can be done by the facilitators increasing on the feedback they give to the learners. This is not possible in the MOOC since usually the numbers are very

high. However, this can be done in high education courses by increasing the online tutors to help in providing learner support and feedback.

Peer feedback played a significant role in ensuring interactions with the course platform. Since all the submissions were assessed through the platform the learners interacted and helped peers get more feedback on their submissions.

Peer assessment was done on final contextualized individual answer. The facilitators developed rubrics that assisted the learners to asses' other learner's submissions. It was emphasized that each learner should give assessment to at least three other learners. The peer assessment was viewed by the learners to help them know how they have been assessed which will help better understanding of the concepts missed out. Learning happens both during provision of peer assessment and receiving peer assessment.

The learners also felt that the course resources helped them in doing the group activity with 68% for 2015 MOOC and 83% for 2016 MOOC. Having course resources that are connected to group activity can help in ensuring effectiveness of the online learning group. Though having indicative course resources to do group activity is important, learners should be allowed to be innovative and bring in new course resources when doing their assignments. This is possible with an online learning community. The learners of the MOOC of 2016 (72%) agreed to the roles and processes for problem solving more than the MOOC of 2015 (43%). This shows that there are better group dynamics in 2016 as compared to 2015 which can be one of the reason for the better completion rate. For purposes of effective social group connection, it is important for the group members to agree on the roles and processes within the group. However, groups build cohesion over time of interactions. This time element should be incorporated in the course structure. This is a very important aspect that can be adopted in higher education to have effective online learning groups. Results also revealed that only a few participants in both MOOCs were frustrated with one or more group members and the group size was big and distracted the group. The group size of five (5) members can bring about effective interaction and group deliberations. Since group size was five that is the reason they felt that they were not distracted by the group size and frustrated with one or more group members. This group size is easy to monitor and the members feel a sense of belonging.

Learners were also asked about the effectiveness of the online learning groups. Forty four percent (44%) felt that it was 70% and above effective, 40% felt that it was 40% - 60% effective, 16% felt it was below 40% effective. This reveals an indication to the right direction with 84% feeling that the effectiveness of the learning groups was above 40%. The organization of the course played a significant role in the effectiveness of the online learning groups. However, this should also be coupled with appropriate online learning groups and activities. This then brought us to question if learning groups were working as elaborated in the next section.

3.4 Are learning groups working?

Learners were asked their perception of online learning groups. Figure 4 shows the percentage of respondents who perceived the statements to be true about their online learning groups in both MOOCs.

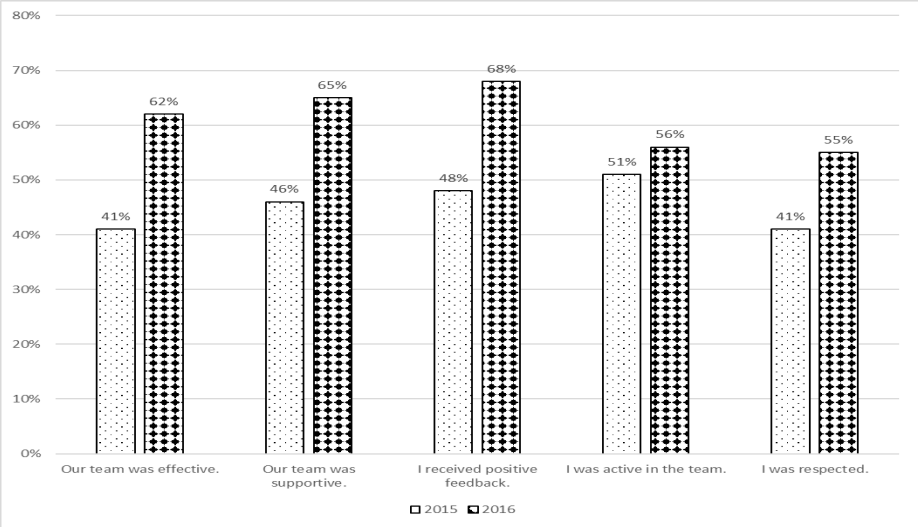

Fig. 4. Are learning groups working

On average 55% of respondents agreed with positive statement about learning groups in 2016 and 40% in 2015. The statements included the following "Our team members were supportive and encouraging each other", "I received positive feedback from my peers". "Our team members respected my opinions". The above statements indicated high percentage of agreement. These helps in motivating and sustaining interaction within learning groups. However, learners never reached levels of sharing jokes during their group discussion which is indication that the groups had not got to high levels of group dynamics as indicated in the Tuckman five stage model [15]. Learners shared jokes in the 2016 MOOC (21%) compared to the 2015 MOOC (13%). These elements are very important aspects of effective online learning groups in helping to motivate members. In higher education, it should be encouraged to let learners know that support, encouragement, positive feedback, respecting opinions from group members are important aspects for effective online learning groups.

Motivation is important for sustainable online learning groups. Motivation is not one-off event but a continuous process throughout the learning group life. Learners agreed that they were motivated by their peer's interaction within the group. One of the learners said, "The more you get quick feedback on your submissions definitely the more you get motivated". Eighty six percent (86%) agreed with the above statements in 2016 and 50% in 2015. For effective online learning groups in higher education group members should be motivated within the group by their peers and facilita-

tors. Gallimore and Tharp [16], suggested that positive feedback encourages learner participation.

Student interactions are important in increasing learning [6]. Interactions are encouraged through course organization. The organization allowed open feedback on all submissions by all the learners. The learners received feedback through comments on their submissions. Though the cafeteria forum was meant for social discussions, it generated a lot of content-related interactions. Learners interacted with classmates using questioning which generated a lot of discussions. Questioning that provoke other learners to think more or read content can help in assisting learning [16]. Some of the examples picked from the forums that used questioning: - "I agree with your thoughts on being successful in learning regardless of the type - good or bad - of experience. Do you think that almost everyone wants to be successful in learning?" and "Not achieving/finishing a task is not always failure; sometimes it is success delayed. What do you think?" This encouraged many learners to interact with classmates through these forums. This therefore is indication that learning groups are working and in the next section we elaborate what did the group help with.

3.5 What did the group help with?

The learners were also asked about how group members helped each other. Figure 5 shows the details of the findings.

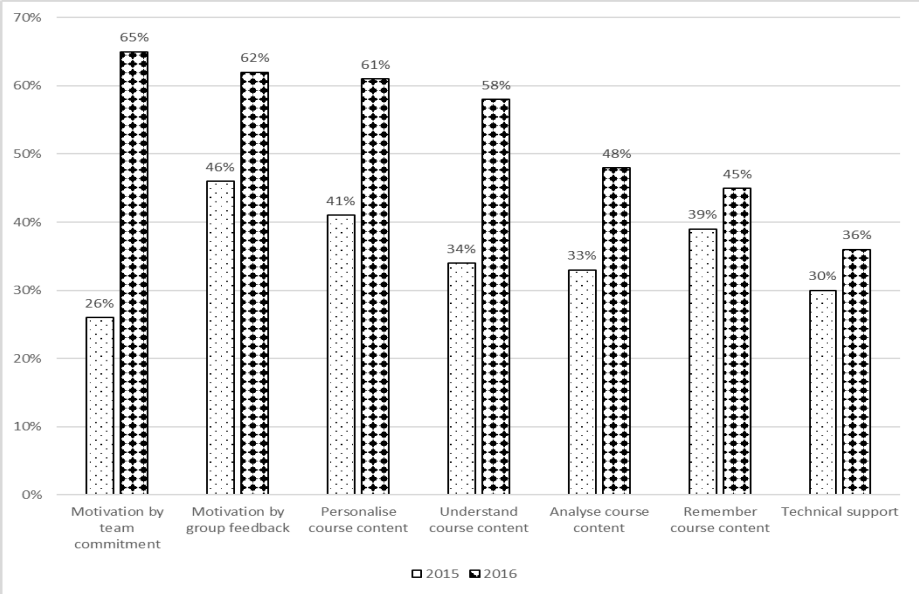

Fig. 5. What did the group help with?

As indicated in figure 5 learners felt motivated by team commitments and group feedback. This agrees with educational psychologists who believe that positive re-

wards play a significant role in encouraging participation and interaction [16]. Learners were given guidelines on how to respond within the groups e.g. encouragement to give positive feedback. Guidelines on how learners should behave are very important to the motivation of learners in online learning groups. This is equally important for higher education. Therefore, encouraging learners to give positive feedback will help in motivating the learning group members. When interactions or commitment within the group are high, the other learners will fear to let down their team members. Motivation is vital in sustaining interactions and learning in learning groups.

Learners were asked their perception of their interactions in learning groups. The percentage of respondents who perceived the statement to be true about their interactions in the learning groups. The statements were required to understand the level of interactions in the groups based on Bloom's taxonomy. The interaction questions were based on the verbs remember, understand and analyze. Remember is based on recalling facts and basic concepts, understand is based on explaining ideas or concepts and analyze is based on drawing connections among ideas. On average 52% of the respondents in 2016 MOOC perceived their interaction to lower levels of remembering and understanding while 37% of respondents in 2015 MOOC. This can be improved by facilitators getting involved in the interaction to provoke for higher level cognitive interactions. However, it is not easy for MOOCs given that the numbers of learners are usually very high. This can be done in higher education by the facilitators provoking learners during their interactions in the groups. Respondents also revealed that they used individual experiences when discussing the course concepts. This helps learners get new knowledge from authentic examples from more knowledgeable peers. The interaction was due to the design of the course which allowed peer feedback and assessment.

There were also forums created with the aim of supporting learners on both technical problems and content. These forums equally received a lot of posts and comments which helped the learners in getting support from other learners and tutors. Because forum interactions are open to all learners and tutors, the interactions were quality assured since corrections are made in case some person gives wrong comment. Learners felt that they can improve their ability to express thoughts online. In 2016, 89% responded in agreement that they could improve their ability to express themselves while there was 50% for 2015 MOOC. This shows that the learners started finding interaction interesting and easy which could be an indication difference in completion rate. Equally the experiences that the learners came with in the course helped others to learn from them. This helps the knowledgeable peers to scaffolding other learners given their firsthand experiences from their work or previous work. The next section explains the tools used by the online learning groups.

3.6 Which tools were used?

This course was run on NovoEd platform but with flexibility to allow learners use other collaborative tools. Though there are so many technologies that can be used for collaboration student revealed that they used the following tools as shown in figure 6.

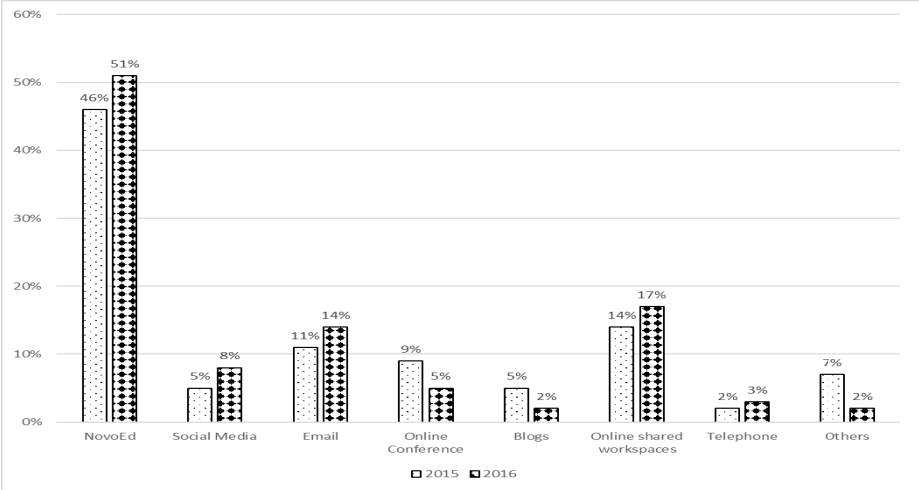

Fig. 6. Which tools were used?

NovoEd was the most used tool, because this was the platform that the course was run. Mostly, the NovoEd tool was used in the collaboration of the learning groups. However, other collaboration tools were also occasionally used.

Eighty two percent (82%) of the respondents felt that they sometimes got lost in the platform and failed to find what they wanted in the 2015 MOOC while 31% for 2016 MOOC. This shows that learners in the second MOOC were more comfortable using the platform than the first MOOC. This has a significant bearing on the effectiveness of a learning group. Likewise, 89% of the respondents in 2015 MOOC also felt that it was difficult for them to learn how to use NovoEd unlike 11% for 2016 MOOC. This might have been because many of the learners who attended 2016 also come back from the 2015 MOOC. This makes them have fewer challenges using the platform. Fewer respondents 14% felt that they were comfortable seeking help via the forum while the 2016 MOOC had 75% who would get help from the forum.

Table 2. Effective collaboration tools

Statement	2015	2016
Our team has used collaborative tools outside NovoEd.	13%	30%
In team interaction, it was sometimes frustrating to use technology.	30%	20%
NovoEd was an effective tool for team work.	46%	62%
Google hangout was an effective tool for team work.	20%	21%

The table 2 shows how learners felt about the effectiveness of the collaboration tools used. It was indicated that tool support in the 2015 MOOC was 29% and 2016 MOOC represented 36%. Participates also revealed about provision of technical support during group work with 13% for the 2015 MOOC and 30% for the 2016 MOOC. Tool usability is important for the success of online learning group.

4 Conclusion

We conclude that the course organization structured for online learning groups has the potential to increase individual participation in groups. As such the course organization, can be an effective mechanism for facilitating online learning group activities in higher education. The course organization removes the known burden of supporting large student numbers reminiscent of MOOCs as it increases interaction among participants. The course organization help in providing clear sets of activities well aligned to the learning goals and resources. The increased feedback mechanism within the course organization is good pre-cursor to participation motivation which leads to low levels of dropout. Therefore, for an effective online learning group the following must be emphasized; well-structured course organization that supports group work, well-structured group activities that have the affordances of online collaboration and connected to the goals of the course, guiding learners on how to motivate others through feedback and questioning, encouraging interaction within a learning group, learning group tool usability and features that have the affordance of group processes and online technical support.

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6 References

[1] Muyinda, P.B., G. Mayende, and J. Kizito, Requirements for a Seamless Collaborative and Cooperative MLearning System, in Seamless Learning in the Age of Mobile Connectivity. 2015, Springer. p. 201-222. https://doi.org/10.1007/978-981-287-113-8_11

[2] Stahl, G., T. Koschmann, and D. Suthers, Computer-supported collaborative learning: An historical perspective. Cambridge handbook of the learning sciences, 2006. p. 409-426.

[3] Aguti, J.N., D. Nakibuuka, and R. Kajumbula, Determinants of Student Dropout from Two External Degree Programmes of Makerere University, Kampala, Uganda. Malaysian Journal of Distance Education, 2009. **11**(2): p. 13-33.

[4] Ayala, G. and S. Castillo. Towards computational models for mobile learning objects. in Wireless, Mobile, and Ubiquitous Technology in Education, 2008. WMUTE 2008. Fifth IEEE International Conference on. 2008. IEEE.

[5] Ashley, P., A Teaching with Technology White Paper. Collaborative Tools. Retrieved on November 1, 2014 from http://www.cmu.edu/teaching/technology/whitepapers/CollaborationTools_Jan09.pdf, 2009.

[6] Anderson, T., Modes of interaction in distance education: Recent developments and research questions. Handbook of distance education, 2003: p. 129-144.

[7] Mayende, G., et al., Facebook Mediated Interaction And Learning In Distance Learning At Makerere University in 8th International Conference on e-Learning, 15 – 18 July. 2014: Lisbon, Portugal.

[8] Ludvigsen, S. and A. Mørch, Computer-supported collaborative learning: Basic concepts, multiple perspectives, and emerging trends. The international encyclopedia of education, 2010. **5**: p. 290-296. https://doi.org/10.1016/B978-0-08-044894-7.00493-0
[9] Mayende, G., et al. Peer assessment based assignment to enhance interactions in online learning groups. in Interactive Collaborative Learning (ICL), 2015 International Conference on. 2015. IEEE.
[10] Collison, G., et al., Facilitating online learning: Effective strategies for moderators. 2000: ERIC.
[11] Salmon, G., et al., Experiential online development for educators: The example of the Carpe Diem MOOC. British Journal of Educational Technology, 2015. **46**(3): p. 542-556. https://doi.org/10.1111/bjet.12256
[12] Salmon, G., et al., Designing Massive Open Online Courses to take account of participant motivations and expectations. British Journal of Educational Technology, 2016. https://doi.org/10.1111/bjet.12497
[13] Jordan, K., Initial trends in enrolment and completion of massive open online courses. The International Review of Research in Open and Distributed Learning, 2014. **15**(1). https://doi.org/10.19173/irrodl.v15i1.1651
[14] Mayende, G., et al. Supporting Learning Groups in Online Learning Environments. in 7th International Conference on Computer Supported Education. 2015. Lisbon, Portugal. https://doi.org/10.5220/0005433903900396
[15] Tuckman, B.W. and M.A.C. Jensen, Stages of small-group development revisited. Group & Organization Studies, 1977. **2**(4): p. 419-427. https://doi.org/10.1177/105960117700200404
[16] Gallimore, R. and R. Tharp, Teaching mind in society: Teaching, schooling and literate discourse in Moll (ed) Vygotsky and education: Instructional implications and applications of socio historical psychology Cambridge university press. 2002.

7 Authors

Godfrey Mayende is a PhD student in the Department of Information and Communication Technology, Faculty of Engineering and Science, University of Agder, Norway and an Assistant Lecturer in the Institute of Open, Distance and eLearning, Makerere University, Uganda. Research interest: Learning Groups, Online Learning, Online Learning Systems, eLearning, Distance Learning.

Andreas Prinz is a Professor at University of Agder in Norway and works with systems engineering for telecommunication, eHealth, and embedded systems. He focuses on modelling, languages and formal methods. He is currently very interested in the use of modern ICT tools for teaching.

Ghislain Maurice Norbert Isabwe is an Associate Professor in Multimedia and eLearning in the Department of Information and Communication Technology, Faculty of Engineering and Science, University of Agder, Norway. His areas of interest include human-centered design of interactive systems; open, distance and e-learning; visualizations and simulations in mathematics education; gamification of learning and mobile learning.

Paul Birevu Muyinda is an Associate Professor and Dean of School of Distance and Lifelong Learning at Makerere University, Uganda. He is an experienced ODeL teacher, researcher and professional. He has research interest in ICT impact evalua-

tion, virtual education, e-learning, distance education; m-learning, online learning, blended learning, open education resources (OER); ICT4E, ICT4D and Massive Open Online Courses (MOOCs). College of Education and External Studies, Makerere University, Uganda.

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Cellular Automata as an Example for Advanced Beginners' Level Coding Exercises in a MOOC on Test Driven Development

Lessons Learned and Suggestions for Improvement

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Thomas Staubitz
Hasso Plattner Institute, Potsdam, Germany
thomas.staubitz@hpi.de

Ralf Teusner
Hasso Plattner Institute, Potsdam, Germany
ralf.teusner@hpi.de

Christoph Meinel
Hasso Plattner Institute, Potsdam, Germany
christoph.meinel@hpi.de

Nishanth Prakash
Brown University, Providence, RI, USA
nishanth_prakash@brown.edu

Abstract—Programming tasks are an important part of teaching computer programming as they foster students to develop essential programming skills and techniques through practice. The design of educational problems plays a crucial role in the extent to which the experiential knowledge is imparted to the learner both in terms of quality and quantity. Badly designed tasks have been known to put-off students from practicing programming. Hence, there is a need for carefully designed problems. Cellular Automata programming lends itself as a very suitable candidate among problems designed for programming practice. In this paper, we describe how various types of problems can be designed using concepts from Cellular Automata and discuss the features which make them good practice problems with regard to instructional pedagogy. We also present a case study on a Cellular Automata programming exercise used in a MOOC on Test Driven Development using JUnit, and discuss the automated evaluation of code submissions and the feedback about the reception of this exercise by participants in this course. Finally, we suggest two ideas to facilitate an easier approach of creating such programming exercises.

Keywords—programming tasks; unit testing; test driven development; MOOC; automated grading

1 Introduction

The well-known Game of Life [7], a John Conway creation, has withstood the test of time among popular programming problems for good reason. It exercises several useful programming concepts (like the use of random numbers, 2-D arrays, functions, loops and recursion), can be extended to include advanced programming concepts and methodology (such as Object Oriented Programming, Design Patterns, Test Driven Development, UI design, Interactive Programming, etc.) and can be scaled to varying levels of difficulty with ease. While some problems in Cellular Automata and Game of Life, are well within the reach of programming novices, others are difficult enough to be considered for advanced programmers in specialized areas (such as parallel programming or ecology modelling, etc.). Most importantly it is fun and engaging to program Cellular Automata and watch their transitions. In this paper, we explore the suitability of Cellular Automata challenges for developing a wide variety of programming assignments, appropriate for audiences ranging from novices to experts. Programming ability basically rests on two pillars. One is formed by the theoretical foundations of knowledge about computers, programming languages, tools and formal methods (i.e. knowledge which is of a declarative nature, for example— being able to state how a "for" loop works). The other is the ability to apply this knowledge hands-on.

The famous adage "I hear and I forget. I see and I remember. I do and I understand", as succinctly put by Confucius, is very much relevant even to this day in pedagogy. But while much of the instructional content focuses on theoretical aspects of computer programming, it is programming assignments and exercises that play a major role in helping students learn programming skills and techniques through practice.

Providing students with quality homework, exercises, and assignments is integral to the success of any course. Particularly so, in introductory courses where the major share of student's learnings comes from [1]. Often however, the tasks set for practice are not considered as a vehicle that can direct learning behaviors in students [2]. To add to this, most programming assignments are what most students would classify as boring: mathematical problems (except games), sorting, string manipulation and others all succeed in helping students to learn the concepts, but few are met with any real enthusiasm and fewer still inspire true creativity [3].

In Section 3 we begin with a study of interesting programming tasks that have been previously used in classroom courses, MOOCs and other instructional settings. In Section 4 we then provide a brief introduction to Cellular Automata, their different types and modelling use cases, and in Section 5 we describe how they can be used as programming tasks in various instructional contexts. We discuss previous work related to this in Section 2 and in Section 6 we present a study on the use of Cellular Automata programming as an exercise task in the context of a MOOC on Test Driven Development using JUnit. We also discuss student submissions evaluation methodology in this exercise and present an analysis on student feedback and reception. In Section 7 we present the next steps that we've already started to implement.

The main contribution of this paper is to explore the various types of problems and the varying levels of complexity and difficulty, that can be constructed using concepts from Cellular Automata and the suggestions how to lower the barrier for teaching teams to provide practical programming exercises to their courses.

2 Related Work

There has been extensive research in Cellular Automata, and the problem of designing programming tasks in computer science pedagogy. However, one of the results of our literature review was that there has been surprisingly little work investigating the utility of Cellular Automata programming problems in computer science education.

Using a series of Cellular Automata modelling examples, Lilly shows how these problems can be used creatively to address problems in the areas of motivation, learning styles, development of modeling skills, and the teaching of technology [5]. While the authors do describe the use of Cellular Automata in classrooms, they do not discuss it from the perspective of computer science pedagogy.

Weeden employs multiple versions of the Game of Life simulation as exercises in parallel programming, including exercises using shared or distributed memory as well as exercises on how to measure the performance and scaling of a parallel application in multicore and many-core environments in [16]. Mache and Karavanic describe their use of the Game of Life as an exercise in teaching parallelism by asking students to speed up a CPU-only implementation by modifying it to use CUDA [17]. Wick employs the Game of Life as a vehicle to teach freshman students Command and Visitor, two important and widely applicable design patterns, by refactoring the Game of Life application [18]. Furthermore, Beniak uses the Game of Life to teach principles of game design and game engine development with Microsoft XNA [19]. Although each of these endeavors explore interesting cases of cellular automata problems used in computer science education, we do not find any holistic discussion on the possibilities in using cellular automata for programming tasks.

3 Programming Tasks

While course lectures impart theoretical knowledge to students, programming exercises and tasks set in the course have the bonus of complementing the lectures by imparting practical knowledge to students. They help students in gaining a deeper understanding of the subject and in enabling them to apply their knowledge in new situations [4].

Guzdial and Soloway propose that this is achieved best by applying tasks in the realm of media. They claim that the current generation[1] of students enjoys learning about array manipulation better if the example results in producing sound more than if

[1] We dare to suggest that previous generations of students might have preferred that as well. Nowadays however, the improvements in technology easily allow to do that.

the task requires sorting student IDs or doing linear searches for employee names [4]. This calls for better use of current technology in pedagogy, where more immersive experiential learning can now be easily created by including manipulation of sound, graphics, and videos in problem contexts.

Feldman and Zelenski suggest that the tasks that are suited best, are those that result in programs that students want to write for the reason that they enjoy running them themselves. Apart from requiring a strong audio-visual component and a high degree of interactivity, they believe that the end result of an assignment must be worth the time and effort required to achieve it, because when students see the end result of a programming assignment as something especially impressive, useful, or fun—a program they would like to have for themselves—they will approach the project with a heightened sense of interest and motivation. Also, writing a programs that can be presented with pride to relatives and friends, significantly increase a beginning programmers sense of accomplishment. [1]

An obvious class of problems that fits the above requirements very well are those of game programming. Very often, the students say that gaming is what got them interested in computers and regardless of where they end up in their careers, many start off with a desire to become game designers. The fun factor in games is what sets tasks in this context apart from the majority of problems assigned. Next to this, games can also hold the potential for integration of almost all of the concepts and techniques taught in a typical CS degree program [3].

Although the Game of Life and other Cellular Automata are not games in the conventional sense, they are found to be equally engaging. There are typically no players, and the game is generally not about winning or losing, but is typically used as a simulation of another system, that runs according to some specified rules. Thus, they combine the benefits of gaming with the benefits and challenges of mathematical exercises.

4 Cellular Automata

A cellular automaton is a mathematical model which has been widely studied in the simulation of various physical, chemical and biological systems. They usually consist of a configuration of "cells" which represent elements of the system being modeled, each of which can be said to be in one of a set of finite number of states. The configuration of these cells can be a single row of cells as in one-dimensional or elementary cellular automata, a grid as in two-dimensional cellular automata, blocks placed in three-dimensional space as in three-dimensional cellular automata or other regular structures such as a grid of hexagonal cells, etc. Each cell has a defined neighborhood, generally depending on the shape and configuration of the cells. The cell itself may or may not be included in the neighborhood. If the cells are in a row, a cell has two neighbors—left and right. If the cells are in a hexagonal grid, a cell has six neighbors. The cells that are located on the margins may have their outer neighbors either defined as dead or as the cells that correspondingly lie on the opposite end of the configuration. The cellular automaton starts with an initial combination of states

of its cells and evolves following a transition function (a set of rules) that define the next states of the cells depending on the current states of their neighbors. The definition of neighbor and the transition function can vary and be complex depending on the system being modeled.

For example, the cellular automaton could be modeling microbial growth, where each cell represents a microbe cell which can be alive or dead, and the rules by which it evolves could be that it survives or is born if there are four or more live adjacent cells, otherwise it dies. The previously mentioned Game of Life is modeled similar to this. Also, a simple two-dimensional Cellular Automaton can model growth of crystals or patterns in snowflakes or on shells. These sequences of transitions are both mathematically interesting as well as aesthetically pleasing when displayed using colors to represent states of the cell [6].

Types of Cellular Automata vary widely in their complexity and modelling ability. While some models can only be used to express a basic idea of a phenomenon, others are accurate enough to be used for prediction. Stephen Wolfram describes this in [25] as:

"Cellular automata are sufficiently simple to allow detailed mathematical analysis, yet sufficiently complex to exhibit a wide variety of complicated phenomena."

Even simple Cellular Automata, such as the Game of Life, are computationally universal, meaning that it is able to compute/model anything computable [12, 24]. From the spots on a leopard to the design of a snowflake to the structure of the human brain, Wolfram is confident that there is a cellular automaton that encodes the design of each [10]. This nature of complex phenomenon emerging from simple systems in Cellular Automata [34], has instigated several scholars to consider the question of whether the underlying model of the universe is a cellular automata populated by digital particles [35, 36]. In the usage of Cellular Automata concepts for programming problems, this variety gives us the ability to tweak difficulty and complexity to suit our needs, to weave interesting concepts together to make an engaging experience for the problem solver, and at the same time stay relevant to topics in Computer Science curriculum.

5 Relevance of Cellular Automata in programming tasks

Jon Conway popularized cellular automata through The Game of Life [12], and Martin Gardner made them reach the public through his columns in Scientific American [7, 8] and his puzzle collection books [9]. Since then, a great number of professional mathematicians, as well as amateurs have contributed to an understanding of the game of life [12, 13, 14, 15], as well as Cellular Automata [20, 21, 22, 23]. Due to their engaging and narrative nature they have also been adopted widely to teach programming concepts.

Apart from their popularity and engaging nature, the most important feature of Cellular Automata problems is the fine grain control they provide to the teacher, in being able to tweak the difficulty of problems by making incremental enhancements to the

problem design. For example, if the problems required to program an Elementary Cellular Automaton following a specific rule, the next difficult problem could require the programming of an Elementary Cellular Automaton using only one array, thus imparting list processing skills to problems solvers. The next addition could be that a general Elementary Cellular Automata generator has to be coded, taking the rule number (a naming convention that maps to a unique transition function) as parameter. The following task could then be to code the Game of Life or any other two-dimensional cellular Automaton using two dimensional arrays which can be scaled then to 3 dimensions, etc. Interesting variations that stimulate one's visualizing ability, could require the Cellular Automaton to wrap around at its edges to resemble a Torus or only to wrap around on the sides as a Mobius strip. For more algorithmic variety and difficulty ranges, problems could require cells of other, non-rectangular shapes such as hexagons; or define unidirectional neighbors or have other such complex definitions of neighborhood.

To include probability concepts, the task can be to design stochastic cellular automata where the transition rules are probabilistic rather than definite (i.e. instead of stating that the cell would be dead in the next state, we say the cell has 80% chance of dying). The states of the cells could be continuous rather than discrete as in Continuous Cellular Automata, which tends to model many Finite Element Analysis implementations [37]. Furthermore, the automaton can be required to have a continuum of locations as in Continuous Spatial Automata or have time as a continuous variable where the state evolves according to differential equations, thus integrating important concepts from Calculus.

The second most important feature is that they provide teachers with the ability to easily integrate a wide variety of programming concepts into the problem. The simpler variants of Elementary Cellular Automata suit best in the procedural programming context. To teach the concepts of Object Oriented Programming (OOP), variations from the simpler cellular automata can be employed. These variations might range from requiring the cells to be movable within the universe of the cellular automaton, to requiring the possibility to nest cells in another cell, thus enabling the student to model an entire ecosystem. Due to its parallelizability, the game can also be coded in Functional Programming paradigms which are most well suited for parallel programming. The variety in the spectrum of Cellular Automata problems recommends them to motivate students. Particularly, visual learners are attracted by the created patterns and encouraged to develop their modeling skills [5]. They are considered to be useful for the development of curricula to teach certain computer technologies [5]. Problems of varying depth can be employed to expose different approaches to solve a task. The arising difficulties can be employed as feedback to improve the teaching material.

Recent investigations by Stephen Wolfram [11] on cellular automata have put forth multiple thought provoking questions on the nature of our universe, on computability and computational irreducibility, and on the epistemology of sciences. His extensive research in these areas have exposed important unanswered question related to theoretical computer science, logic, Artificial Intelligence, Mathematics and Philosophy.

Deep questions such as these can generate sustained interest among some students that may lead them eventually to take up a career in Computer Science research.

6 Case Study (Use of Rule 54 Elementary Cellular Automata Programming Task in Test Driven Development using JUnit MOOC)

In the following we will discuss the findings of a case study that we conducted during our MOOC "Introduction to Test Driven Development in Java and JUnit." The course was designed as a two-week workshop on the basics of Test-driven Development. The target group were participants with basic Java knowledge. About half of the participants had also participated in the previous Java programming course that we had offered a year earlier. The majority of the participants considered themselves to have good to excellent knowledge in programming. A couple of questions that we have asked to double-check these self-evaluations seem to confirm this. An in-depth examination of this survey will follow in a future paper. The course had 2799 registered participants[2]. 950 of these never showed up[3]. 283 participants received a Record of Achievement. 322 of the participants answered a couple of questions in our course end survey. The age of the participants ranged from less than 20 to 69 years. Most of the participants were male, and not surprisingly, as the course was offered in German, lived in Germany. The overall feedback on course quality, course length, etc. was good to very good. The difficulty of the course was considered medium (3 on a 5 point Likert scale ranging from 1-very easy to 5-very difficult.)

We picked the Rule54 Automaton among the one-dimensional automata rules, as it was the best fit for our requirement of being easy to comprehend and, therefore, being suitable for beginners. Any other rule would have been possible as well, coming along with its own advantages or disadvantages.

6.1 Rule 54 CA

A rather simple form of cellular automaton is the one-dimensional (elementary) cellular automaton, which consists of a single row of cells. Each cell starts with a given initial state and evolves depending on the states of its left and right neighbor.

In our course on Test-driven Development and JUnit, we provided an exercise based on an Elementary Cellular Automaton called *Rule 54*. The participants were asked to implement and test this Cellular Automaton, which is constituted by the following set of rules:

1. If the cell and both neighbors are dead in the current state, then the cell is dead in the next state.

[2] We always employ the number of enrollments at course middle as the basis for our calculations, as these are the participants who still have a realistic chance on finishing the course with a certificate

[3] These are what we call no-shows. Platform users that register for a course but in the end do not ever visit a single item of the course.

2. If the cell and both neighbors are currently alive, then the cell is dead in the next state.
3. If the cell and one of its neighbors are currently alive, then the cell is dead in the next state.
4. If the cell is alive and both neighbors are dead in the current state, then the cell is alive in the next state.
5. If the cell is dead and at least one of the neighbors is alive, then the cell is alive in the next state.
6. The cells beyond the Cellular Automaton's boundaries are considered to be dead.

All mentioned rules can be represented as combinations of 3 binary numbers (In the following, they are sorted by the binary value represented. 0 represents dead and 1 represents alive).

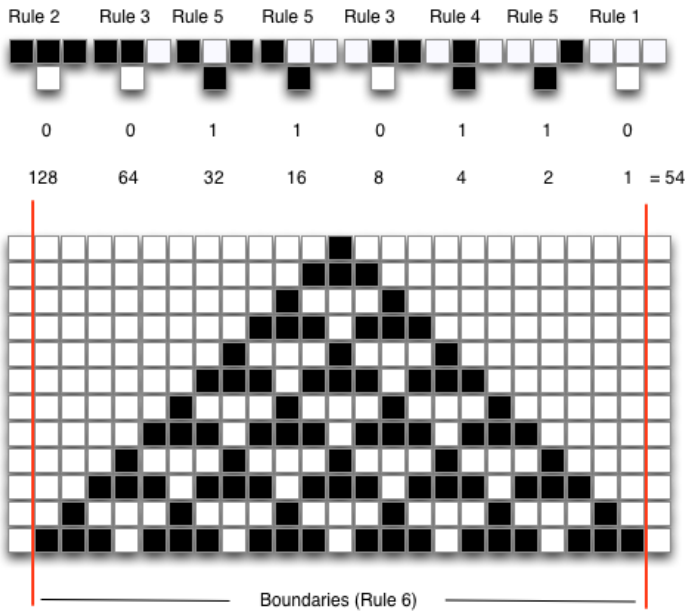

Fig. 1. Rule 54 Cellular Automaton. Each row represents one iteration at a time.

When the output shown in Figure 1 is written horizontally, it denotes a binary number, which is the number 54 in decimal representation. Hence, this automaton is named Rule 54. The rules and an exemplary evolution of a row with only one cell alive in the center of the row are shown in Figure 1.

Cellular Automata based on building rules, such as in the example above, also give the teacher the ability to scale the problem complexity in small steps. For example, the first few problems for getting started can be to ask the student to implement specific rules such as Rule 54 or Rule 30, each having their own characteristic properties -- Rule 54 is amphicheiral [33], Rule 30 is chaotic [32], Rule 110 has been shown to be capable of universal computation [30, 31]. The usual algorithms employed to pro-

gram a cellular automaton, typically use iteration or recursion on discrete time units, such as the number of days of evolution undergone. More advanced participants may even deduce an elegant closed form solution for certain problems such as Rule 54, in which the decimal value of the *n*th iteration is given in closed form by:

$$a(n) = \begin{cases} \frac{7}{15}\,(4^{n+1} - 1) \text{ for } n \text{ odd} \\ \frac{1}{15}\,(4^{n+2} - 1) \text{ for } n \text{ even} \end{cases}$$

A follow up task for the students might be to code a general elementary cellular automaton, which takes the rule number as an input. Finally, the students can be asked to add an interactive display. Thus, the teacher is provided with a plethora of settings to tweak the complexity of the problem depending on the need of the situation.

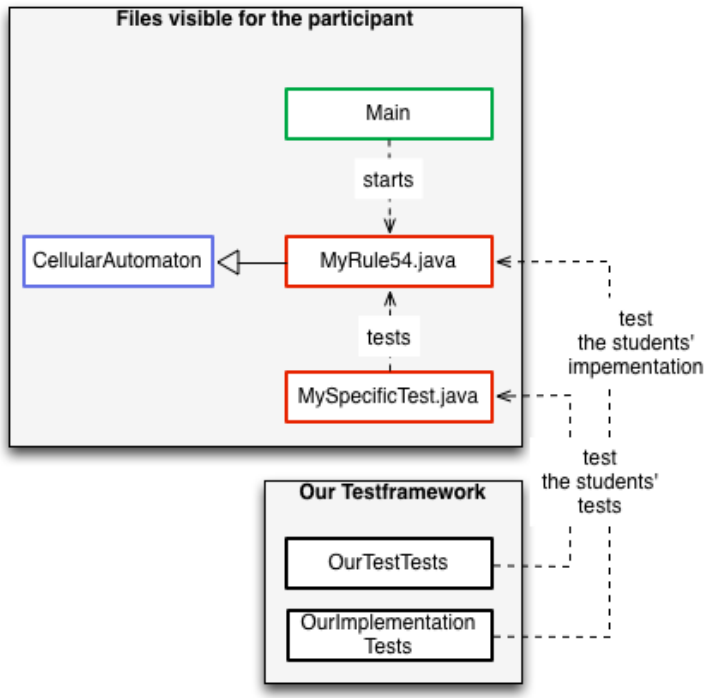

Fig. 2. Next to the part that is visible to the participants, the assignment contains a hidden part, which mainly consists of two types of tests: 1. tests that test the behaviour of the participants' implementation and 2. tests that test if the tests that have been provided by the participants test the correct things. They have to catch a certain amount of errors and have to pass against the correct implementation. The files that have been provided to the students were an abstract class that defined the required methods to be implemented (blue border), a starter class (nothing needed to be done here-green border), and the scaffolds for a test class and the according implementation class (red border). The red-bordered classes had to be completed by the students.

In our course we employed the problem of Rule 54, which allowed us to test varied classes of test cases. These classes ranged from test cases that check the implementation on the main paths of the code to those that check the numerous edge paths, such as single celled or double celled automata. The original design of the problem included an additional feature, which allowed the Cellular Automaton to be in a continuum having the cells that are bordering the automatons limits wrap around and lie next to each other instead of having the space beyond the limits of the automaton being populated by dead cells. This feature required a larger number of unit test cases to check the additional paths of Cellular Automaton wrapping, but since the course was targeted towards a novice audience and was supposed to run only for two weeks, we decided not to include it in the final problem statement.

6.2 Testing and Assessment

In the assessment of student submitted programs, there has been a wide use of dynamic testing using a battery of unit test cases that characterize and differentiate the correct solutions from the wrong ones [26, 27, 28, 29]. Dynamic testing provides precision in measuring correctness, but is not comprehensive. To come up with an exhaustive set of test cases that catches every possible mistake that a student can make is infeasible. Hence, there is an inherent necessity for static code analysis to assess students' solutions comprehensively.

In our JUnit course, we encouraged the participants to follow the test first approach. According to this approach, tests are written first, then the actual solution is implemented. The participants iteratively improved their solutions as well as their tests, until they finally submitted their work for assessment. For the evaluation of these submissions we assessed their solution as well as their tests. To evaluate their solution, we used a battery of test cases that solely check the correctness. We are currently working on a more comprehensive assessment strategy by means of static code analysis.

Our online assessment platform is configured to allow the solution as implemented by the participants to be run for a maximum time of 20 seconds. The better implementations, thus, had plenty of time to succeed on all our assessment tests. As a side effect the timeout acts as a filtering mechanism to weed out incorrect solutions.

When the participant clicks on the "Score" button, our test suite is run against the participant's solution of the problem and then our tests are run against their tests as shown in Figure 2.

Dynamic Analysis of JUnit tests using Mutation testing: To provide thorough coverage for all possibilities, the Cellular Automata exercise would have required a large amount of test cases. To keep the workload for the teaching team in the zone of feasibility, we turned to the use of mutation testing, a common technique used in the software industry to evaluate the quality of software tests. The participants' test submissions were analyzed on the two dimensions of correctness and thoroughness. Participants' test solutions were not only required to pass a minimum number of tests against our correct "gold" solution, but it was also required that at least one or more of their test cases failed against a certain minimum number of our intentionally incor-

rect/mutated "coal" solutions. We required students to pass only a minimum number of test cases against gold and catch only a minimum number of coals as opposed to 100 percent or complete correctness and thoroughness in order to relax requirements as the course was targeted towards novices. Students were informed that their tests would be tested against a correct implementation as well as multiple other incorrect implementations. Code stubs, which included an instantiated constructor of the classes of gold or coal solutions, were provided to the students with appropriate directions on how to use them.

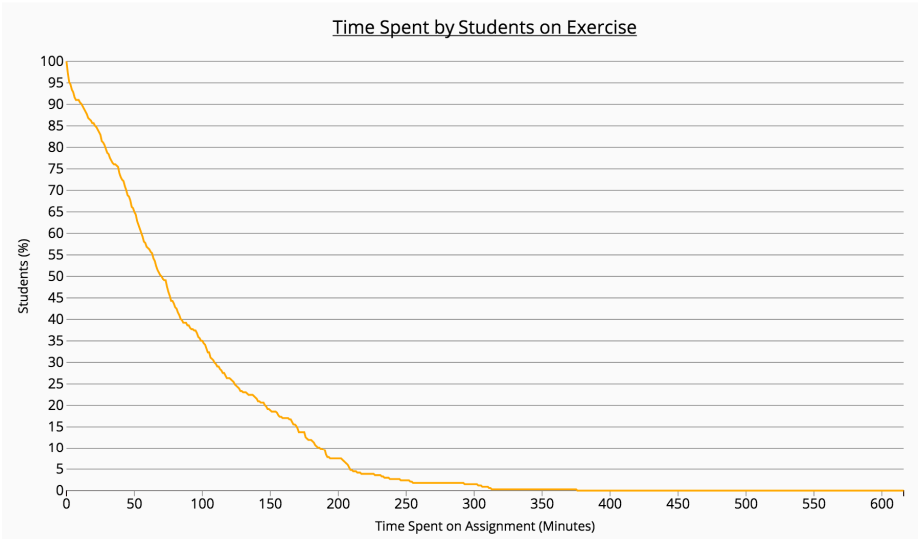

Fig. 3. The average time spent on the assignment by the participants was about one and a half hours. In comparison, we, the members of the teaching team spent a total of about 10 hours on the platform alone to create, maintain and troubleshoot the assignment. Additionally, we spent at least as much time that has not been recorded on designing and implementing the assignment.

6.3 Feedback and Reception

We have not done a formal evaluation on the participants' perception of the Cellular Automata assignment. The discussions in the forum, however, ranged from "the exercise was way too easy, it should have required us to write more test cases" to a couple of very detailed discussions that showed that the involved participants had problems with the task but were eager to solve it.

We have, however, some data on the way the users interacted with the task. 364 course participants started the Cellular Automata assignment, which was one of the main alternatives to earn the Record of Achievement. We recorded 26.968 intermediate submissions. 279 participants finally submitted the assignment. The average score for the assignment was about 90%. The time that has been spent by the participants on the assignment ranged from about 1 minute to about 10 hours, counting only those

that at least solved it to some extent. One minute to solve the exercise seems to be hardly impossible with "legal" means. It was rather difficult, although not impossible to download the code and work on it offline as it contained a couple of hidden files used for testing. We, therefore, cannot eliminate the possibility that some of the very fast users have been cheating. Another explanation would be that they have teamed up to work on one of the participants' assignment and then just had to copy/paste and resubmit the solution for the other user. As we always encouraged the participants to collaborate, this would be a perfectly acceptable approach. The number of candidates is low anyhow. No more than about 5-6 participants finished the assignment in less than 5 minutes.

7 Required Adjustments

Creating programming tasks, using cellular automata or not, requires much time and effort on the side of the teaching team. Particularly, writing sound, but not too rigid test cases is very important for the learning impact of these exercises. Sloppily designed test cases rapidly result in frustration among the participants, particularly among the novices who cannot yet distinguish if they are just not getting it right or if the tests are wrong. For the teaching team, this situation is problematic as well; soon the users' requests for help need to be handled, exercises and test cases need to be fixed, discussions in the forums need to be calmed down, etc. In the following sections, we will introduce two approaches to cover this problem from different angles. In Section 7.1 we will discuss how to increase the pool of well-maintained, high quality programming exercises by offering a platform to share these exercises among teachers.

In Section 7.2 we will discuss how replacing or enriching the current approach of dynamic testing by means of static code analysis can simplify the creation of coding exercises and improve their quality.

7.1 Exercise Management and Exercise Sharing

A coding exercise repository has been on our mind since we started to create our first programming course. During the preparation for the course on Test-driven Development the need for such a repository grew more urgent. This course raised the bar quite a bit as it's topic required us not only to test the code of the participants but also the tests that they have written. Not only did we need more tests, but also the tests' complexity grew. In discussions with colleagues, we soon realized that we were not the only ones who are facing this problem. One of the challenges for such a repository is that there are many auto-graders out there and the exercise repository needs to be flexible enough to allow exporting and importing from at least the more popular ones as otherwise it would not be widely used, thus degrading it to a mere management tool for our own purposes and not contributing to the solution of our problem.

We, therefore, analyzed two other auto-graders to find a common basis of required data to be stored with each exercise. Praktomat[4], developed at the KIT in Karlsruhe, Germany and INGInious[5], developed at the Université Catholique de Louvain in Belgium are, as well as CodeOcean[6], our own auto-grader, open source projects on github (see footnotes). Finally, we looked for a standardized data exchange format that serves our purposes. The idea here was not to reinvent the wheel but rather to use a format that is already developed by a community of possible future users of this platform. The common formats that first come in mind, such as Common Cartridge by the IMS Global learning consortium[7] or the IEEE Learning Object Metadata (LOM) [38] didn't really meet our requirements as they are serving different purposes. We finally found the ProFormA-XML format, which perfectly suits our needs. [39]

Further developments of this Coding Repository, which is also available open source on github[8] will be covered in a future paper.

7.2 Static Code Analysis

Quality in Software Engineering refers to either quality in the functional aspects or to the structural aspects of the software. Functional aspects reflect the correctness of the software solution, which is essentially a measure of how well the software conforms to a given design, based on functional requirements or specification. Structural aspects on the other hand refer to other non-functional aspects of the software such as robustness, maintainability, that support the delivery of the functional requirements. Our testing solutions are currently exclusively through dynamic testing using a battery of unit test cases or through manual evaluation by means of peer assessment, where feasible. The emphasis has been on checking functional aspects of code solutions so far, while the structural aspects have been largely left behind. While dynamic testing does provide great precision in measuring correctness, they are not comprehensive. It is very difficult to come up with an exhaustive set of test cases that catch every possible mistake that a student can make.

Many programming languages provide tools that test the code on behalf of predefined quality metrics, code-style and best practices. The huge advantage of this approach is that these metrics need to be defined only once per programming language to be taught and then can be employed for all programming exercises the same way. In contrast to this, dynamic tests have to be written for each exercise separately and often have to be adjusted when the exercise is changed.

Particularly for peer assessed programming exercises, additionally a security aspect comes into play. Currently, we ask our students to run the code of their peers on their home computers to check if the running program fulfils certain requirements. This comes with a certain risk. If the grading is based on a static code analysis, the peers would not have to run the code of their peers anymore. Instead they just need to run a

[4] https://github.com/KITPraktomatTeam/Praktomat/
[5] https://github.com/UCL-INGI/INGInious
[6] https://github.com/openHPI/codeocean
[7] https://www.imsglobal.org/cc/index.html
[8] https://github.com/openHPI/codeharbor

static code analysis on the submission. Running such a static code analysis is way less risky than running the code of more or less untrusted persons.

Moving away from functionality as the mere target of assessment, opens the door towards other important aspects of learning to write clean code:

Reliability—measures the risk of potential application failures and defects injected due to modifications made to the software. By means static code analysis, reliability can be measured e.g. in terms of good exception handling, null pointer dereference detection, or the safe use of inheritance and polymorphism.

Efficiency—deals with time and space used by the software. It can be measured by checking for appropriate interactions with expensive and/or remote resources, data access performance and data management, memory, network and disk space management.

Security—poor coding practices and architecture increase the likelihood of potential security breaches. Issues that can be found statically are bad input validation, buffer overflows, improper locking, or SQL injection.

Maintainability—includes many subtopics, such as e.g. modularity, testability, or reusability. It not only refers to readability of code and documentation, but also to observance of design and architectural rules. Important checks with regard to ensure high maintainability are e.g. cyclomatic complexity, unstructured and duplicated code, or an excessive program size.

We've started to run our first experiments with industry strength tools for static code analysis. For now, we measured the performance requirements of such a solution employed in our auto-grader. The results so far are encouraging. These experiments will also be discussed in a future paper.

8 Conclusion

We have shown that Cellular Automata can be employed as practical programming exercises, suitable for novices as well as experts. They are a rewarding basis for developing interesting and motivating tasks. To design and to implement them, however, puts a high workload on the shoulders of teaching teams. The same applies for other interesting programming tasks as well. This is particularly true, when they are graded solely by means of dynamic testing. Alternative sources to determine a grade for the code that has been provided by a student, therefore, should be further investigated. Static code analysis is a promising candidate. Another approach is to combine automated code assessment with peer assessment. Next to simplifying the process to create programming exercises, it is necessary to provide the possibility to exchange and share programming exercises with other educators, to allow reuse and evolution of programming tasks.

9 References

[1] T. Feldman and J. Zelenski, "The quest for excellence in designing cs1/cs2 assignments," in *ACM SIGCSE Bulletin*, ACM, vol. 28, 1996, pp. 319–323.

[2] A. Carbone, J. Hurst, I. Mitchell, and D. Gunstone, "Principles for designing programming exercises to minimise poor learning behaviours in students," in *Proceedings of the Australasian conference on Computing education*, ACM, 2000, pp. 26–33. https://doi.org/10.1145/359369.359374

[3] K. Becker, "Teaching with games: The minesweeper and asteroids experience," *Journal of Computing Sciences in Colleges*, vol. 17, no. 2, pp. 23–33, 2001.

[4] M. Guzdial and E. Soloway, "Teaching the nintendo generation to program," *Communications of the ACM*, vol. 45, no. 4, pp. 17–21, 2002. https://doi.org/10.1145/505248.505261

[5] H. A. Lilly, "The use of cellular automata in the classroom," in *Proceedings of the 1995 ACM/IEEE conference on Supercomputing*, ACM, 1995, p. 16. https://doi.org/10.1145/224170.224204

[6] R. A. Bosch, "Integer programming and conway's game of life," *SIAM review*, vol. 41, no. 3, pp. 594–604, 1999. https://doi.org/10.1137/S0036144598338252

[7] M. Gardner, "The fantastic combinations of john conways new solitaire games," *Mathematical Games*, 1970.

[8] M. Gardner, "Cellular automata, self-reproduction, garden of eden and game life," *Scientific American*, vol. 224, no. 2, p. 112, 1971.

[9] M. Gardner, Wheels, life, and other mathematical amusements. WH Freeman New York, 1983.

[10] S. G. Krantz, The proof is in the pudding: The changing nature of mathematical proof. Springer Science & Business Media, 2011. https://doi.org/10.1007/978-0-387-48744-1

[11] S. Wolfram, *A new kind of science*. Wolfram media Cham- paign, 2002, vol. 5.

[12] E. a. Berlekamp, Winning Ways for Your Mathematical Plays, Volume 2: Games in Particular. London, England: Academic Press, 1982, vol. 2.

[13] P. Callahan, *Creating life: Conway's life miscellany web page*, http://www.radicaleye.com/lifepage/, [Online; accessed 18-09-2016].

[14] W. Poundstone, The recursive universe: Cosmic complexity and the limits of scientific knowledge. Courier Corporation, 2013.

[15] R. Wainwright, "Lifeline-a quaterly newsletter for enthusiasts of john conway's game of life," *Issues*, vol. 1, 1971.

[16] A. Weeden, "Parallelization: Conway's game of life," [Online; accessed 18-09-2016].

[17] J. Mache and K. L. Karavanic, "Teaching parallelism with gpus and a game of life assignment," *Journal of Computing Sciences in Colleges*, vol. 28, no. 1, pp. 200–202, 2012.

[18] M. R. Wick, "Using the game of life to introduce freshman students to the power and elegance of design patterns," in *Companion to the 19th annual ACM SIGPLAN conference on Object-oriented programming systems, languages, and applications*, ACM, 2004, pp. 103–105. https://doi.org/10.1145/1028664.1028706

[19] S.Beniak, *Creating life: Conway's life*, http://gamedevelopment.tutsplus.com/tutorials/creating-life-conways-game-of-life–gamedev-558 , [Online; accessed 18-09-2016].

[20] E. F. Moore, "Machine models of self-reproduction," in *Proc. Symp. Appl. Math*, vol. 14, 1962, pp. 17–33.

[21] J. Myhill, "The converse of moore's garden-of-eden theorem," *Proceedings of the American Mathematical Society*, vol. 14, no. 4, pp. 685–686, 1963. https://doi.org/10.1090/s0002-9939-1963-0155764-9

[22] G. A. Hedlund, "Endomorphisms and automorphisms of the shift dynamical system," *Theory of computing systems*, vol. 3, no. 4, pp. 320–375, 1969. https://doi.org/10.1007/bf01691062

[23] T. Toffoli, "Computation and construction universality of reversible cellular automata," *Journal of Computer and System Sciences*, vol. 15, no. 2, pp. 213–231, 1977. https://doi.org/10.1016/S0022-0000(77)80007-X

[24] P. Rendell, "This is a turing machine implemented in conway's game of life," *Website. www. rendell-attic. org/*-gol/tm.htm, 2005.

[25] S. Wolfram, "Statistical mechanics of cellular automata," *Reviews of modern physics*, vol. 55, no. 3, p. 601, 1983. https://doi.org/10.1103/RevModPhys.55.601

[26] C. Douce, D. Livingstone, and J. Orwell, "Automatic test-based assessment of programming: A review," *Journal on Educational Resources in Computing (JERIC)*, vol. 5, no. 3, p. 4, 2005. https://doi.org/10.1145/1163405.1163409

[27] M. Wick, D. Stevenson, and P. Wagner, "Using testing and junit across the curriculum," in *ACM SIGCSE Bulletin*, ACM, vol. 37, 2005, pp. 236–240.

[28] U. v. Matt, "Kassandra: The automatic grading system," 1998.

[29] M. Joy, N. Griffiths, and R. Boyatt, "The boss online submission and assessment system," *Journal on Educational Resources in Computing* (JERIC), vol. 5, no. 3, p. 2, 2005. https://doi.org/10.1145/1163405.1163407

[30] M. Cook, "Universality in elementary cellular automata," *Complex systems*, vol. 15, no. 1, pp. 1–40, 2004.

[31] M. Cook, "A concrete view of rule 110 computation," *ArXiv* preprint arXiv:0906.3248, 2009.

[32] E. Weisstein, *Rule 30*, http://mathworld.wolfram.com/Rule30.html, [Online; accessed 18-09-2016].

[33] E. Weisstein, *Rule 54*, http://mathworld.wolfram.com/Rule54.html, [Online; accessed 18-09-2016].

[34] F. Berto and J. Tagliabue, "Cellular automata," in *The Stanford Encyclopedia of Philosophy*, E. N. Zalta, Ed., Summer 2012, 2012.

[35] A. Ilachinski, Cellular automata: A discrete universe. World Scientific, 2001. https://doi.org/10.1142/4702

[36] J. P. Crutchfield, "The calculi of emergence: Computation, dynamics and induction," *Physica D: Nonlinear Phenomena*, vol. 75, no. 1, pp. 11–54, 1994. https://doi.org/10.1016/0167-2789(94)90273-9

[37] Wikipedia, *Continuous automaton*, https://en.wikipedia.org/wiki/Continuous_automaton [Online; accessed 8-September-2016]

[38] Learning Technology Standards Committee of the IEEE. Draft standard for learning object metadata. Technical report, IEEE, 2002. http://129.115.100.158/txlor/docs/IEEE_LOM_1484_12_1_v1_Final_Draft.pdf

[39] Sven Strickroth, Michael Striewe, Oliver Müller, Uta Priss, Sebastian Becker, Oliver Rod, Robert Garmann, Oliver J. Bott, and Niels Pinkwart. Proforma: An xml-based exchange format for programming tasks. *eleed*, 11(1), 2015. ISSN 1860-7470. URL http://nbn-resolving.de/urn:nbn:de:0009-5-41389.

10 Authors

Thomas Staubitz is a Research Associate at the Hasso Plattner Institute (HPI), where he is working on openHPI, the HPI's MOOC platform.

Ralf Teusner is a Research Associate at the Hasso Plattner Institute in Potsdam, Germany.

Nishanth Prakash currently is a student at the Department of Computer Science at Brown University, Rhode Island, US.

Christoph Meinel is the CEO of the Hasso Plattner Institute and the Chair of the Internet Technologies and Systems group.

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Industrial Leadership that Inspires

Managerial Communication as an Emerging Pedagogical Focus in Engineering

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Pia Lappalainen
Aalto University, Language Centre
Leipzig University, Language Centre
pia.lappalainen@aalto.fi

Abstract—To explore the characteristics of effective industrial leadership, this work embarked on a quantitative effort to investigate requirements posed on leaders. Contrary to previous competence-based studies, the present work examined leader qualities more broadly through substantive knowledge, personality traits, socio-emotive skills, cultural awareness, and ethics and values. A particular aim was to conceptualize and operationalize effective leader behavior in industries to identify relevant and targeted foci for engineering pedagogy. Statistical analysis and factor analysis of the data from 503 respondents on 81 leader traits or skills shows that leadership that elicits positive organizational outcomes is founded on such leader personality dimensions as reliability, and such socio-emotive skills as self-leadership, emotional stability, inspiration and assertive communication.

Keywords—industrial leadership, management behavior, personality, socio-emotional competence

1 Introduction

In the contemporary world of hyper-competition, organizations strive to leverage client satisfaction and financial gains by strengthening their employees' psychological connection with work, severely undermined by such macroeconomic forces as social upheaval and political turmoil. At the core of the convulsion, the concept of work is undergoing a change affecting not only organizational and team outcomes but also the context of individuals' psychological processes [1]. This strengthens the business case for understanding and building the psychological capital in the workplace and for identifying measures preventing psychosocial risks [2]. When these risks materialize, they incur monetary costs through absenteeism, presenteeism, decreased productivity, increased employee turnover, deteriorated organizational citizenship behavior, and change resistance [3]. On societal and national levels, negative mental load at work impairs citizen health, increases mortality, lowers the average retirement age, and reduces quality of life, while straining the public welfare and health care systems [4].

Contrastively, a rapidly expanding body of research has established an association between e.g. employee affective commitment and organizational outcomes, or between workplace climate and physiological, psychological and economic effects [5]. To better understand positive socio-emotive factors and their impacts at work, organizational studies have taken an interest in the motivational role of job resources as facilitators of task accomplishment, exploring aspects such as autonomy and social support available at the work community [6], [7]. Representatives of the positivity school have found support for the role of positive emotions as factors yielding positive impacts on individuals' thoughts, actions and physiology, ultimately incrementing their psychological, physical, social and intellectual resources [8], [9]. As the most salient and immediate source of emotional contagion, leadership is increasingly viewed as predictive of employee attitudes, performance, well-being and motivation [10], [11], with follower motivation for higher job performance having been described as the prime function of leadership. As mediators, organizations and management studies have proposed e.g. job design, organizational interaction culture, inspiring visions, or leader's charisma, attractiveness, authenticity, motivational language [12], [13] or leadership style [14].

The myriad quests to understand the sources and foundation of effective organizational leadership have introduced various paradigms, drawing on supervisor influence on subordinates [15]. Traditionally, leadership has been approached through three different theory lines: the first examined leader attributes, the second leader behavior, and the third, contingency theory acknowledged the role of situational variables or contingency factors in moderating leadership effects. However, a group of leadership styles exists that does not fit into any of these theories directly as it cuts across several theories, directing the focus to a mixture of leader traits, conduct and contextual variables [16], [17]. Extrapolating from the core features of the above schools, the answer could be found with the constructivist theory, according to which leadership emerges in the relationship between leaders and followers [18], [19]. Sparked by this theory, the focus of leadership research has subsequently shifted from leader actions to the perceptions of the followers, taking the premise that without followers, there is no-one to be led. This consideration for employee evaluations evidences a paradigmatic transition from top-down to bottom-up approaches to leadership [20].

Perplexingly, despite the early recognition of the role of managerial communication as manifestation of leadership style and its significance for employee outcomes, the study of managerial communication competence has centered mainly on elementary and mechanical skills such as clarity of expression, appropriateness of language, timeliness of response, and attentiveness [21]. Until recently, the role of leaders' non-verbal transmission and influence strategies in enhancing human capital has been largely ignored [22], [23], [24].

The presently burgeoning research on leader emotions and emotive communication has made significant advances, drawing upon theories such as motivational language theory and speech act theory, but the full grasp of factors impacting the quality of leader-member exchange is yet to be achieved [25]. While support is available for claims on the role of leaders' individual differences and dispositional variables in interaction with subordinates [26], the communicative building blocks contributing to

successful leadership are insufficiently understood. Effective management communication has not been operationalized on a level concrete enough to explain for incidents perceived as inspiring, motivating and persuasive by subordinates.

Leadership research has been criticized for strong segmentation and neglect to integrate findings from different approaches in a way that would allow simultaneous examination of leader traits, behaviors, situational factors and follower cognitions [27]. To respond to this call and to more solidly establish the anatomy of effective leadership, this study sliced supervisory competence requirements into a set of 81 personal qualifications found through literature review, to examine which dispositions, abilities, and skills are regarded as most pertinent for successful industrial leadership. The findings are based on a sample of 503 respondents to an online survey. Factor analysis was employed to yield the components of leader performance.

This research offers three contributions to the field of engineering education: 1) it furthers understanding of personal qualifications in industrial leadership, 2) it repositions communication competence in relation to industrial leadership, and 3) it builds a framework operationalizing managerial communication in the industrial set-up. Together these efforts not just advance the theory of leadership and management but also provide concrete instruments for organizations and university educators by suggesting priorities for engineers' competence development.

2 Advances in Managerial Communications Research

Management research has advanced significantly since the early curiosity about ways in which leaders exercise influence on their followers to create a sense of organizational coherence [28], [29], [30]. The fundamental tenets of such influence have traditionally centered on the transactional principles of exchange in the leader-follower interaction, while directing growing attention to the personal capabilities of the leader, with studies of leader pathologies paving the way [31]. Subsequently, much is known about traits enabling dysfunctional leadership, but to date, only little about leaders' relational or influence strategies, or the implicit motives, thinking styles and attitudes that drive leader behaviors and outcomes and the ways in which they are perceived by subordinates [32], [33], [34].

Supervisor behaviors and abilities in interaction deserve more research attention, however, as they are known to be associated e.g. with organizational commitment and employee performance and well-being [35]. Owens and Hekman [36] contend that positive organizational outcomes such as effectiveness and high-quality leader-follower relationships can be traced to leader humility. Leaders featuring positive characteristics through e.g. hope, optimism, resilience and self-esteem have been found to promote follower positivity and performance [37]. Kelloway et al. [38] take it as far as to claim that the prime purpose of organizational leaders is to spread positivity to their followers, due to the number of desired impacts that positive emotions induce in terms of creativity, efficiency, scope of attention, physical skills and health, optimism, resilience, commitment and coping at work. Overall, leader positivity seems indicative of subordinate perceptions of leader effectiveness, suggesting that

leaders' socio-emotive skills bear an impact beyond subjective experiences. This, together with the accumulating reports on positive organizational scholarship or positive organizational behavior, substantiates a focus in this study on leaders' psychological capital [39].

Further, Lappalainen [40] challenged the advantage of the mathematically intelligent in leader positions by investigating managers' socio-emotive competence, personality dispositions and analytical intelligence and comparing them to subordinate perceptions. She found that social and emotional intelligences correlated on a significant level with subordinate cognition of effective leadership, whereas analytical intelligence yielded no correlation at all. Four out of fourteen personality dimensions seemed predictive of success in supervisory tasks. It should be noted that these four dimensions, sociability, inspiration, concrete perception, and optimism, all drive and color communication behavior and could therefore broadly be regarded also as components of communicative competence.

2.1 Leadership as Emotional Work

Historically, managing stable and predictable tasks involved prescription of specific goals and directions, allowing leaders to direct, or to exercise their legitimate, positional or informational power to punish and reward [41]. Managing in the postmodern world is, however, much more complex, calling for less coercive and more empowering means. As an example of power responding to today's demands for employee's self-directed action and proactive behaviors, leaders' social power, referent or expert power, means that the individual is either seen in high esteem or regarded as possessing unique knowledge, granting him or her subsequent authority. Social power is linked with influencing strategies and contributes largely to organizational citizenship behavior, which in turn promotes individual and organizational effectiveness [42].

From the exercise of formal authority or power, leading others has gradually morphed into emotional work - feelings and affect are deeply intertwined with leading, leader outcomes, and follower outcomes [43]. The motivation and need to follow have deep emotional roots, the profound motive deriving from craving for care and attention, and a sense of identity and purpose - when allowing ourselves to be controlled, we feel protected and secure. The leader provides meaning and simplifications in otherwise complex surroundings [44].

Emotionality at work typically refers to concern for job design, workload, and job satisfaction [45] but also to the quality and impact of an individual's affective responses to work. Studies show that the share of time an employee feels net positive affect matters for job satisfaction, more than the intensity of that affect. This implies that employers should rid their staff of minor irritations that accumulate into a mental load that eventually tips the balance towards constant negative affect. Contrastively, frequent positive reinforcements, although less intense, elevate job attitudes [46].

Leaders can adopt emotionally intelligent *behaviors* in the workplace but emotionality poses demands also for *personality*. Certain traits such as extraversion and emotional stability have been found to correlate with leadership emergence [47]. Personality moderates an individual's perceptions as leader-like but requires further investiga-

tion as a predictor of job performance or actual leadership effectiveness. In other words, perceived influence is not equivalent to effectiveness. The other way round, the absence of certain traits may hinder the individual from emerging as a leader [48]. To add to the expanding body of research on positive leadership, this work embarked on an empirical effort to analyze the attributes that contribute to leader impact.

3 Theoretical framework and research questions

Among industrial leadership competences, the professional, transferrable leader skills have earned unanimous recognition, yet a systematic definition and conceptualization of leaders' generalist abilities remains to be achieved [49]. This may result from the nature of leader requirements: leadership competence is increasingly viewed through the lens of communicative competence [50], which is undergoing a conceptual controversy of its own. Further, the systematic analysis of leader communication is perplexed by tension between two competing approaches: leader qualifications can be examined either as learnable skills or as biological personality traits [51].

For the present study, however, the divide between skills and traits remains irrelevant; instead, it suffices to acknowledge that the pivotal personal qualities comprise a mix of learnable skills and personality origins, be they inherent, genetic, biological or the result of conscious skilling or life history. This research subsequently limits its scope to the manifested or behavioral level of these qualities, that is, how these traits or skills are perceived by organizations. The overall research objective to further the understanding of leader qualifications is broken down to two research questions (RQ):

RQ1: What is the make-up of leaders' personal managerial qualifications?

RQ2: What qualifications matter most in leadership tasks?

The categorization serving as the basis of the empirical research was derived from a literature review of studies conducted in work psychology, leadership, organizational communication, and personality psychology. The aim was to map out the diverse competence areas intervening in leader tasks, resulting in a grouping that is not exhaustive, nor does it attempt to suggest a solid typology or prioritization, but rather serves as a first attempt to direct investments in engineering graduates' leadership education.

3.1 Categories of Leader Competences

In industry, technical or substantive expertise alone seldom guarantees effective contextual behavior, which is known to turn field-related knowledge into productivity and profitability [52]. The study of bottom-up leadership must involve also follower perceptions and a subsequent focus on the leader's relational abilities. These process skills address lifelong learning, learning to learn, critical thinking, cooperation, communication, teamwork, intercultural cooperation, organizational understanding and project management. These represent the socio-cultural dimensions that are becoming

increasingly important as globalization intensifies the demands for flexible, socially adept and communicative engineering teams [53].

This paradigm shift manifests itself also in leader requirements: today's leadership theory has departed from the industrial foci on hierarchy, control and division of labour and moved to a post-industrial accent on relationships, networks, trust, ethics and participation [54]. This also reflects a shift in research emphases: where leadership was earlier the subject of psychology studies, it is presently examined through the lens of social psychology, interested in the role of the individual as a group member in a social setup [55].

Consequently, postmodern leadership in industrial operating environments is far from static. The complex temporal conditions have subjected work communities to societal and social forces that urge leaders to assume roles that largely differ from those of their modern antecedents. Heroic, hierarchy-based headship labelled as charismatic, inspirational, visionary, transformational or transactional, among others, was based on the social authority of an individual believed to endow extraordinary gifts and powers. This divine notion of leadership is gradually morphing into a more mundane, constant earning of leader status in inter-human interaction where employees are no longer regarded as subordinates but rather as equal partners [56].

The advanced technologies of today, disappearance of market boundaries, transforming customer expectations, and the subsequently modified operating principles in the engineering world are further moulding managerial competence requirements [57].

These trends set the stage for the analysis of managerial communication that proves effective in the psychological and cognitive processes of the post-industrial workplace. The following sections review literature on today's working life skills, and, in particular, recent findings on competences pertinent to managerial tasks. They broadly categorize managerial competences into five areas: 1) substantive expertise, 2) personality traits, 3) socio-emotive skills, 4) cultural skills, and 5) ethics and values. It should be noted, however, that these categories are broad and at times overlapping, and merely serve as a theoretical point of departure for the empirical work.

Substantive expertise: Functional Job Analysis examines leader activities through behaviours regarded as universal in the managerial setup. The foundation of effective leadership has traditionally been laid on first-rate substantive expertise but is increasingly expected to extend beyond domain-specific capabilities. This expertise is a prerequisite in the five main managerial functions, comprising 1) planning and problem solving, 2) viewing, as well as the three functions of action: 3) independent action, 4) leadership and 5) cooperation [58].

Present membership of many teams, networks and communities simultaneously requires not only subject-related technological expertise, but also soft skills and self-leadership enabling employees to integrate thinking, feeling and behavior[59]. Resultatively, where managers were earlier hired and promoted largely on the basis of their technical or substantive skills, they presently face mounting demands for personal qualifications such as social skills and self-leadership ability. It should be underlined, though, that substantive expertise, be it theoretical, practical or strategic, takes an undeniable role in the build-up of professional expertise and managerial

credibility. As substantive expertise is domain-specific, this study investigates it only narrowly and superficially through theoretical knowledge, practical experience, insight, and academic argumentation.

Personality: In addition to observable personality traits that have traditionally enjoyed a dominant position as descriptors of personality, other variables such as motives and cognitive styles deserve attention, especially in the context of organizational life. Motives and cognitive styles are purposive-cognitive factors and causal agents that relate to behavior and have predictive value. More specifically, motives constitute drivers for action functions and cognitive styles for planning and problem solving, which explains why they are worthy of examination in the work context.

This study addresses bipolar personality dimensions that moderate the five universal leadership functions, including achievement motive (competitive achievement and focused achievement), leadership motive (action leadership and inspiration), cooperation motive (sociability, listening and reliance), cognitive style (orientation, perception and thinking), and attitudes (ambiguity-change, optimism and self-image) [60].

Socio-emotive skills: One of the most intriguing organizational processes is interpersonal communication, not from the viewpoint of information exchange, but in particular, from the point of view of the innuendos, feelings and conscious and subconscious messages that employees convey. The recent paradigm in communication studies consequently discriminates between traditional linear views of communication as one-way information transmission, and more recent understanding of communication as a social process involving emotional exchange, culture formation and relationship build-up [61]. What is of interest in the context of leadership research is that numerous studies have demonstrated that the social or relational abilities of the leader and his or her inspirational communication strategies are associated with successful employee outcomes [62].

The present study departs from the definition of socio-emotive competence either as biological or learnable and chooses to focus on its manifested, behavioral expression in the work context [63]. This is important due to the connection between a leader's mood and the subsequent mood of his subordinates. The connection is grounded on the design of the human brain, and because of this so-called mirroring process, huge expectations are placed on a leader, as his emotions tend to shift into the registers of those in interaction with him. What is noteworthy is that moods can be transmitted also nonverbally, because emotions can be conveyed even in silence, through body language. Although every participant in a culture adds his or her own touch to the mixture of personal footprints, those of leaders have the strongest impact, since their messages bear most weight because of the role assigned to them. They manage meaning and interpretations for the entire organization, even when not expressing their thoughts consciously, intentionally or out loud. Their responses and bodily conduct are followed closely and modelled on, and this is how they set the emotional standard for the work environment [64].

Emotional intelligence or socio-emotional intelligence is founded on two levels of capacity: intrapersonal or emotional, and interpersonal or social intelligences, further divided into self-awareness, self-management, self-motivation, social awareness and relationship management. A fundamental aspect of socio-emotional intelligence is the

reflection and understanding of one's own emotions, and self-reflection and self-awareness are generally recognized as the most important and effective managerial tool. Effective self-awareness facilitates self-motivation and emotional regulation, which helps prevent emotions from rising to a level that causes stress and problematic behaviour. There is evidence that those capable of regulating their emotions by means of rational thinking are physiologically, cognitively and socially healthier. Strong intrapersonal, or self-leadership, skills form the platform for social fluency. Social awareness allows the individual to read, interpret and tolerate others' emotions, and those capable of capitalizing on this knowledge by attuning their conduct to the moods of others are regarded as socially skilled [65].

Social fluency can prove particularly useful for those in charge: adoption of soft influence tactics positively facilitates organizational change and makes leaders appear as more effective in the eyes of the followers. Although not always recognized as a communication skill, effective listening has been claimed to distinguish the best managers and leaders [66]. They do not merely listen, but they give their full attention, attune to the other person's feelings, paraphrase and ask questions to understand better. Their attunement is not jeopardized by preoccupation; full listening maximizes physiological synchrony and emotional alignment, resulting in their presence being truly felt by the other person [67].

The present research subsequently includes question items that represent both the one-way information dissemination process and the two-way meaning creation and relationship build-up process.

Cultural skills: Changes stemming from globalization accentuate socio-cultural aspects in employee competence development to accommodate the needs of individuals representing increasingly different educational backgrounds, cultures, and nationalities in the workplace [68]. Global markets and value network necessitate both scientific-technical and economic competences that bolster production, but also socio-cultural awareness and mental flexibility bridging the gaps between the growingly multi-cultural staff. Simultaneously, cultural and generic knowledge such as methodological, communicational, and personal skills facilitating the functioning of multicultural corporate teams are called for, as industrial tasks become less repetitive, linear and mechanistic. Resultatively, today's employees experience disengagement that stems from the cultural boundaries characterizing the professional work settings and impeding the build-up of social connections and trust. The increase in workforce diversity also complicates managerial work, requiring cross-cultural skills such as cultural empathy and adaptability [69].

This is why generic socio-emotional skills such as empathy, flexibility, tolerance for diversity and openness are included in the present study. However, as they represent generic socio-emotive skills, they were not grouped under their own heading in Table 1.

Ethics and values: Recent managerial wrongdoings have set higher and more public requirements for leader conduct that is in line with organizational values and societal morale. More than ever, employees need to be ethically oriented and socially responsible, capable of contributing to a just, equitable and sustainable world. Further, they are expected to master ethical thinking and implementation both on the macro-

ethical level related to their profession and the micro-ethical level of the individual [70].

Consequently, the present survey includes question items addressing sustainability, values thinking, integrity and responsibility.

3.2 Research framework

Traditionally, managerial communication studies have focused on the interaction between managers and subordinates, neglecting to adopt an individual differences perspective and paying, until recently, little attention to an individual leader's personal capabilities. To fill the related research gap, the present work embarked on a quantitative empirical effort to conceptualize and operationalize effective leader behaviour in today's industry. The study examined leadership broadly through five categories of competence pertinent for managers' professional artistry: 1) substantive knowledge, 2) personality (motives, thinking styles and attitudes), 3) socio-emotive skills, 4) cultural skills, and 5) ethics, values and attitudes. Under such a definition of leader capabilities, the five areas were further divided into 81 skills, abilities or personality dimensions, responded to on a Likert scale 1 (not important) – 6 (highly important).

This approach is founded on our previous study that identified effective leadership to comprise the substantive foundation, the personality level of intrapersonal or self-leadership ability, and the manifested level that shows as communication behavior, as depicted in Figure 1. The key finding was that effective managerial conduct centers on assertion (alpha .88) emotional availability (alpha .90) and inspiration (alpha .81), found on the interpersonal or skills level.

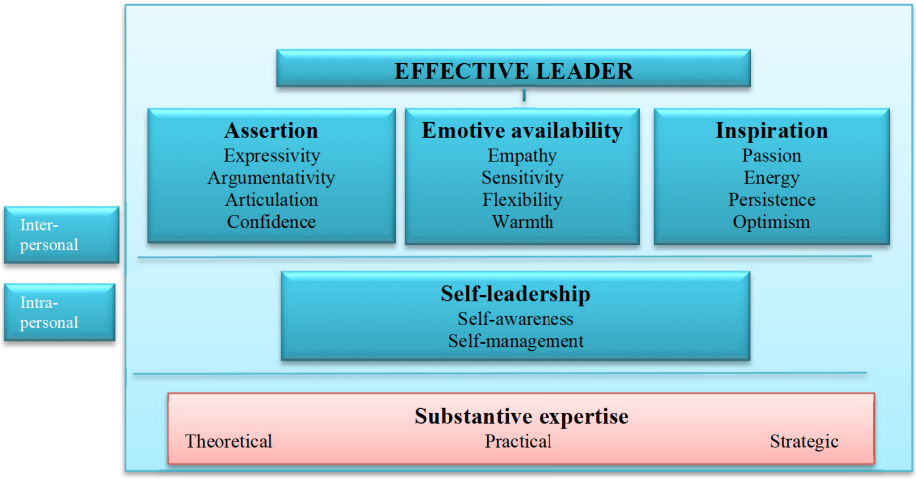

Fig. 1. The foundation of effective leadership.

3.3 Method and data collection

The present research focused on examining today's leader requirements in industry. The ultimate aim was to support organizational HR processes, particularly recruitment and competence development. The survey asked for 1) respondent details (age, gender, and experience from supervisory tasks), 2) respondents' industry or field, and 3) respondent insights into supervisory requirements (81 question items as listed in Table 1). The survey was devised with the Webropol tool. An online survey link was emailed to corporate HR managers, who then forwarded the invitation email to their staff. Responding took approximately 20 minutes.

The question items were derived from the literature review and two previously established instruments:

1. **the Work personality index WOPI 360:** WOPI 360 is a multi-source appraisal for the comprehensive assessment of managers' universal competences in terms of competent, good and desired behaviors. The 45-item questionnaire incorporates descriptive statements typical in managerial work situations. The respondents use a 1-7 graphic rating scale to appraise how descriptive each statement is of the target person's habitual behavior (1 = not at all descriptive; 7 = very descriptive). [71]
2. **Emotive Communication Test (ECT): The** ECT is an other-report tool measuring managerial socio-emotive skills. Its origin is in the Affective Communication Test ACT, which assesses nonverbal expressiveness and the affective elements that are essential to face-to-face and interpersonal relations in effective leadership. The instrument is valid for examining one's ability to transmit emotion, and to lead and inspire others, thanks to its focus on such dimensions of expressivity as communication ability, emotionality, extraversion, responsivity, and empathy. The ECT is an adaptation that was modified to suit the Scandinavian operating culture, addressing self-regulation, assertion, agreeableness and emotional accessibility through 20 questions on a 1-7 graphic Likert scale (1=not at all descriptive; 7=very descriptive) [72].

Table 1. The categories under examination and the related question items.

SUBSTANTIVE KNOWLEDGE	**1.** is competitive
2. has theoretical domain expertise	**3.** makes decisions based on fact
4. has practical, hands-on experience	**5.** is optimistic and hopeful
6. has insight and visionariness	**7.** is realistic and considers facts
8. has academic writing skills	**9.** believes in him/herself
SOCIO-EMOTIONAL SKILLS	**10.** is self-aware and realistic about him/herself
11. communicates clearly and unambiguously	**12.** recognizes his/her flaws and weaknesses
13. communicates in an original and personal style	**14.** is assertive and decisive
15. expresses empathy	**16.** likes to help others
17. discusses issues outside work	**18.** relies on others
19. is good at summarizing	**20.** willingly leads others
21. expresses emotions	**22.** is compliant, follows advice and rules
23. gives positive feedback	**24.** is flexible, capable of compromising
25. gives critical feedback	**26.** is not impulsive or easily provoked
27. accepts critical feedback	**28.** is goal-oriented and determined
29. is an enthusiastic public performer	**30.** is efficient and a high achiever
31. inspires and motivates others	**32.** carefully considers every decision
33. hugs or touches in emotional situations	**34.** makes decisions in a speedy manner
35. tolerates failure and disappointments	**36.** is systematic and organized
37. has a sense of humor	**38.** solves problems analytically
39. expresses opinions assertively	**40.** is intuitive and relies on instinct
41. doesn't avoid emotional situations	**42.** remains calm and collected even in crises
43. is collegial and expresses solidarity	**44.** takes responsibility for the atmosphere
45. communicates negative issues face-to-face	**46.** is punctual and a good time-manager
47. makes sure his/her messages are understood	**48.** tolerates routines
49. is sensitive to other people's moods	**50.** is intelligent
51. negotiates skillfully	**52.** thinks critically
53. keeps others up-to-date and shares information	**54.** is good at motivating him/herself
55. networks and participates actively	**56.** seems content and happy
57. masters small-talk	**58.** is entrepreneurial
59. admits his/her mistakes	**60.** wants to develop as a human being
61. apologizes when necessary	**62.** adapts easily to change
63. is emotionally intelligent	**64.** is warm and agreeable
65. is credible and convincing	**66.** is balanced and at peace with him/herself
67. is energetic and enthusiastic	**ETHICS, VALUES AND MORALE**
PERSONALITY	**68.** does not compromise his/her values
69. is inspired by new ideas and change	**70.** is absolutely honest in every situation
71. focuses on detail	**72.** takes responsibility for his/her wellbeing and self
73. focuses on the bigger picture	**74.** takes responsibility for others and their wellbeing
75. is extraverted and sociable	**76.** is concerned for the environment and sustainability
77. is a good listener	**78.** tolerates and respects diversity
79. is creative and innovative	**80.** is reliable
81. is willing to experiment with new ideas	

The data were gathered from organizations that employ engineers. As can be seen in Table 2, most respondents in the sample represented the private sector (engineering, commerce, finance), and the rest the public sector (higher engineering education or research, health care, city administration). Anonymous responses were received from altogether 503 respondents, out of which 269 were male and 234 female. In the sample, 190 respondents were 40 years or above, and 303 under, and 308 had managerial experience and 195 not (Table 1).

Table 2. Respondent fields.

Field of operation	n
Engineering industries	119
Finance	75
Commerce	63
Engineering education, or research	79
Health care	9
Other	158

4 Results and conclusions

The results from the sample of 503 respondents to the online survey indicate that regardless of respondent age, gender, managerial experience and field, such emotive skills and personality dimensions that form the foundation for self-leadership are prioritized highest in industrial leader quality requirements. These included the ability to deal with emotionally difficult situations: receiving critical feedback, admitting one's mistakes and apologizing. Managers are also expected to be balanced, implying that impulsive behavior is destructive in managerial tasks. Further, managers are expected to manage traditional information dissemination duties and to actively deliver and spread relevant information. In the sample of 503 respondents, the top ten item averages were as shown in Table 3.

Table 3. Top ten item averages in the sample

Question item	average	Stand. dev	deviation	median	
1.is reliable	5,53	0,66	0,27	6	personality
2.gives positive feedback	5,43	0,74	0,74	6	socio-emotional
3.keeps others up-to-date and shares information	5,42	0,71	0,71	6	socio-emotional
4.accepts critical feedback	5,40	0,70	0,70	6	socio-emotional
5.communicates negative issues face-to-face	5,37	0,79	0,79	6	socio-emotional
6. communicates clearly and unambiguously	5,32	0,72	0,72	5	socio-emotional
7.inspires and motivates others	5,30	0,76	0,76	5	socio-emotional
8. apologizes when necessary	5,30	0,82	0,82	5	socio-emotional
9. expresses opinions assertively	5,28	0,75	0,75	5	socio-emotional
10. admits his/her mistakes	5,23	0,84	0,84	5	values and ethics

No major differences can be found between male and female respondents, as can be seen in Table 4. Nine out of ten items were identical on the two rankings, with only one difference: where men viewed "admits his/her mistakes" as an essential leader requirement, women prioritized "remains calm and collected even in crises".

Table 4. Top ten item averages for male and female respondents.

Male		Female	
is reliable	5,52	is reliable	5,56
accepts critical feedback	5,39	keep others up-to-date and shares information	5,55
gives positive feedback	5,36	gives positive feedback	5,54
communicates negative issues face-to-face	5,31	communicates negative issues face-to-face	5,49
keep others up-to-date and shares information	5,29	accepts critical feedback	5,45
apologizes when necessary	5,27	communicates clearly and unambiguously	5,42
expresses opinions assertively	5,26	inspires and motivates others	5,4
admits his/her mistakes	5,24	apologizes when necessary	5,38
communicates clearly and unambiguously	5,23	expresses opinions assertively	5,29
inspires and motivates others	5,21	remains calm and collected even in crises	5,28

Respondents' managerial experience did not induce major differences in responses, either, as shown in Table 5. Eight out of the ten items on the top ten list are identical, with only two differences: those with managerial experience value "inspiration and motivation" and the ability to "communicate clearly and unambiguously", whereas those with no experience in managerial roles prioritized the ability to "remain calm and collected even in crises" and "practical, hands-on, field-related expertise".

Table 5. Top ten items for those with experience in managerial tasks and for those with none.

Has managerial experience		No managerial experience	
is reliable	5,53	is reliable	5,49
gives positive feedback	5,41	accepts critical feedback	5,38
accepts critical feedback	5,39	expresses opinions assertively	5,36
keeps others up-to-date and shares information	5,33	communicates negative issues face-to-face	5,36
communicates negative issues face-to-face	5,29	remains calm and collected even in crises	5,28
apologizes when necessary	5,28	apologizes when necessary	5,25
inspires and motivates others	5,27	has practical, hands-on, field-related experi-ence	5,23
communicates clearly and unambiguously	5,26	gives positive feedback	5,21
admits his/her mistakes	5,25	admits his/her mistakes	5,2
expresses opinions assertively	5,23	keeps others up-to-date and shares infor-mation	5,18

When examining the averages per respondent field, some peculiarities emerge. Table 6 demonstrates that all the fields within the study value managerial "reliability", "positive feedback" given by the manager, manager's abilities to "accept critical

feedback" and "communicate difficult issues face-to-face", and managers who "share information and keep others up-to-date".

Table 6. Top ten items per field.

Engineering		**Finance**	
is reliable	5,37	is reliable	5,57
gives positive feedback	5,29	communicates negative issues face-to-face	5,5
accepts critical feedback	5,27	keep others up-to-date and shares information	5,47
apologizes when necessary	5,25	communicates clearly and unambiguously	5,38
inspires and motivates others	5,22	accepts critical feedback	5,38
communicates clearly and unambiguously	5,21	gives positive feedback	5,3
expresses opinions assertively	5,19	expresses opinions assertively	5,28
communicates negative issues face-to-face	5,19	focuses on the bigger picture	5,27
keeps others up-to-date and shares info	5,16	remains calm and collected even in crises	5,27
recognizes his/her flaws and weaknesses	5,09	apologizes when necessary	5,27
Engineering education or research		**Healthcare**	
is reliable	5,75	has practical, hands-on, field-related experience	5,71
gives positive feedback	5,58	gives positive feedback	5,71
communicates clearly and unambiguously	5,54	expresses opinions assertively	5,71
inspires and motivates others	5,54	accepts critical feedback	5,57
keeps others up-to-date and shares info	5,54	is balanced and at peace with him/herself	5,57
communicates negative issues face-to-face	5,51	is reliable	5,57
accepts critical feedback	5,48	takes responsibility for the atmosphere	5,43
apologizes when necessary	5,43	communicates negative issues face-to-face	5,43
remains calm and collected even in crises	5,42	makes sure his/her messages are understood	5,43
is good at summarizing	5,37	keeps others up-to-date and shares info	5,43
Commerce		**Other**	
is reliable	5,69	gives positive feedback	5,53
keep others up-to-date and shares info	5,56	accepts critical feedback	5,49
gives positive feedback	5,49	is reliable	5,48
accepts critical feedback	5,44	communicates negative issues face-to-face	5,47
admits his/her mistakes	5,36	keeps others up-to-date and shares information	5,43
apologizes when necessary	5,36	expresses opinions assertively	5,37
has practical, hands-on experience	5,31	communicates clearly and unambiguously	5,36
communicates negative issues face-to-face	5,31	inspires and motivates others	5,34
inspires and motivates others	5,3	remains calm and collected even in crises	5,34
expresses opinions assertively	5,25	admits his/her mistakes	5,34

Some differences emerged when analyzing differences between fields. Quite logically for a sector that operates in citizen health and security, healthcare prioritizes practical, field-related expertise highest. The sample of the "Other" field comprised

mostly employees from city administration, which, in the absence of more tangible incentives and bonus programs, probably long for recognition and feedback from their leaders. In finance, skills in clear and frank information transfer are of the essence, which can be expected in an industry where even the tiniest inaccuracies in details can induce major financial risks or loss.

What was regarded as least important for managers in all the fields was "hugging or touching in emotional situations", which could be a cultural trait in the Finnish society. Similarly, competitiveness, an original or personal communication style, and reliance on others were not deemed important, nor were academic writing skills or small-talk. These findings apply to all respondent groups, to both genders, to those with or without managerial experience, to younger and older participants. Subordinates apparently do not wish to serve leaders that are driven by a strong competition motive but rather appreciate social motives in them. On the other hand, they want their managers to be assertive, without a need to rely on others or to look for others' acceptance. Workplace interaction should focus on work and the substance matter, small-talk is not valued. A common, plain and ordinary communication style suffices that does not even have to be academically sophisticated.

4.1 Factor analysis

The data acquired from the 503 respondents was treated with SPSS for factor analysis (main component analysis, varimax rotation in use), examining the differences between respondents with and without managerial experience. The aim was to identify the competences required in managerial work that are regarded as pivotal for organizations.

The five strongest factors in the sample of respondents with no managerial experience emerged as shown in Appendix 1 in their order of strength: 1) emotional stability, 2) agreeableness, 3) self-leadership, 4) efficiency and energy, and 5) conscientiousness. The first three categories are of personality origin and manifest themselves strongly in interaction with others as self-regulation ability, lack of impulsiveness, approachability and self-discipline. It is interesting that substantive knowledge explains for leadership to the least extent.

In the category of respondents with managerial experience, the five strongest factors were, in their order of strength: 1) agreeableness, 2) self-leadership, 3) emotional stability, 4) conscientiousness, and 5) assertion. Again, personality-driven attributes were accentuated in respondent perceptions, showing that managers understand the value of interaction and the quality of their relationship with the followers. The emphasis on conscientiousness probably stems from the competitive and performance-valuing operating environment in today's organizations and the demands its poses for drive and achievement. Assertion offers no surprise, as firm and convincing ethical communication has generally been valued by other studies, too.

5 Discussion

Traditionally industrial managers have regarded emotions as an element that disturbs the rational operation of organizations but are beginning to understand that humanity goes hand in hand with good performance. An increasing body of evidence has confirmed the mediating role of leader affects and emotional intelligence for industrial performance. Post-modern employees recognize that the fundamental or primal task of leadership is emotional, to prime good feeling in those they lead by creating resonance that allows the best in people to be unleashed. This good feeling in the community facilitates the build-up of a reservoir of positivity, which brings added value as the decisive factor driving productivity and the overall performance of the organization.

This study set out to break leadership down into its essential components, to support university curriculum development and organizational competence development by identifying the key constructs of successful leadership. The analysis revealed that organizations place huge expectations on their leaders in terms of their personality development and socio-emotive abilities. This study showed that the most accentuated expectations are directed to leaders' self-leadership ability; the most crucial component of managerial interaction seems to be the ability to control one's behaviour in a way that conveys balance, warmth and stability as this promotes approachability and ensures communication of critical information also bottom-up.

While self-awareness and self-leadership are beneficial in bringing balance and happiness to one's life, their appropriate and purposeful application in a way critical for the entire organization takes place, first and foremost, through reliable, ethical and value-based leader conduct that secures the fundamental legitimacy of the organization. By demonstrating self-leadership, the leader can serve as an example in accepting one's weaknesses, apologizing for one's mistakes, accepting criticism and appreciating others' successes and effort, but also in motivating oneself for competence development, resilience and personal growth. Further, motivational and inspirational leader communication styles, active listening skills, and spreading of positive energy and passion for the organizational mission are known to contagiously infect the work community with joy of work and dedication and elevated levels of achievement and performance.

In order for this to materialize, the engineering education needs to incorporate themes such as self-leadership and self-reflection into the degree curricula to ensure a solid basis for constructive dialogue and positive communication in industries. Besides serving engineering communities through more versed and effective leadership, such a reform will allow engineering graduates, be they leaders or subordinates, to lead more satisfactory – and productive – lives characterized by warm relationships and genuine interaction.

6 References

[1] Okhuysen, G.; Lepak, D.; Ashcraft, K.; Labianca, G.; Smith, V.; Steensma, H. (2013). Theories of Work and Working Today. Introduction to special topic forum. *Academy of Management Review*, 38(4), 491-502. https://doi.org/10.5465/amr.2013.0169

[2] Kelloway, E.; Weigand, H.; McKee, M.; Das, H. (2013). Positive Leadership and Employee Well-Being. *Journal of Leadership & Organizational Studies*, 20(1), 107-117. https://doi.org/10.1177/1548051812465892

[3] Chan, M. & McAllister, D. (2014): Abusive Supervision through the Lens of Employee State Paranoia. *Academy of Management Review*, 39(1), 44-66. https://doi.org/10.5465/amr.2011.0419

[4] Hassard, J; Teoh, K.; Cox, T.; Dewe, P.; Cosmar, M.; Grundler, R.; Flemming, D.; Cosemans, B.; Van den Broek, K. (2014): Calculating the cost of work-related stress and psychosocial risks. *European Agency for Safety and Health at Work*, European Risk Observatory, Literature Review, ISSN: 1831-9351.

[5] Kopperud, K.; Martinsen, Ø.; Humborstad, S. (2014). Engaging Leaders in the Eyes of the Beholder: On the Relationship Between Transformational Leadership, Work Engagement, Service Climate, and Self–Other Agreement. *Journal of Leadership & Organizational Studies*, 21(1), 29-42. https://doi.org/10.1177/1548051813475666

[6] Solis, E. & Monroy, V. (2014). Between love and war: The effects of affective commitments. *Proceedings of the Academy of Organizational Culture, Communications and Conflict*. 19(2), 3-4.

[7] Bakker, A.; Albrencht, S.; Leiter, M. (2011). Key questions regarding work engagement. *European Journal of Organizational Psychology*, 20(1), 4-28. https://doi.org/10.1080/1359432X.2010.485352

[8] Fredrickson, B. & Levenson, R. (1998): Positive Emotions Speed Recovery from the Cardiovascular Sequelae of Negative Emotions. *Cognition and Emotion*, 12(2), 191-220. https://doi.org/10.1080/026999398379718

[9] Fredrickson, B. & Branigan, C. (2005): Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition and Emotion*, 19(3), 313-332. https://doi.org/10.1080/02699930441000238

[10] Kelloway, E.; Weigand, H.; McKee, M.; Das, H. (2013). Positive Leadership and Employee Well-Being. *Journal of Leadership & Organizational Studies*, 20(1), 107-117. https://doi.org/10.1177/1548051812465892

[11] Thiel, C.; Griffith, J.; Connelly, S. (2015). Leader-Follower Interpersonal Emotion Management. Managing Stress by Person-Focused and Emotion-Focused Stress Management. *Journal of Leadership & Organizational Studies*, 22(1), 5-20. https://doi.org/10.1177/1548051813515754

[12] Grant, A. (2012). Leading with Meaning: Beneficiary Contact, Prosocial Impact, and the Performance Effects of Transformational Leadership. Academy of Management Journal, 55(2), 458-476. https://doi.org/10.5465/amj.2010.0588

[13] Sullivan, J. (1988). Three Roles of Language in Motivation Theory. *Academy of Management Review*, 13(1), 104-115.

[14] Strom, D.; Sears, K.; Kelly, K. (2014). Work Engagement: The Roles of Organizational Justice and Leadership Style in Predicting Engagement among Employees. *Journal of Leadership & Organizational Studies*, 21(1), 71-82. https://doi.org/10.1177/1548051813485437

[15] Steele & Plenty (2015). Supervisor-Subordinate Communication Competence and Job and Communication Satisfaction. *International Journal of Business Communication*. 52(3), 294-318. https://doi.org/10.1177/2329488414525450
[16] Hautala, T. (2005). *Personality and transformational Leadership. Perspectives of Subordinates and Leaders*. Vaasa University. Acta Wasaensis, 145. Business administration 61, Management and Organization.
[17] Kort., E.d. (2008). What, after all, is leadership? 'Leadership' and plural action. *The Leadership Quarterly,* 19, 2008, 409-425. https://doi.org/10.1016/j.leaqua.2008.05.003
[18] Delbecq, A.; House, R.; de Luque, M.S.; Quigley, N. (2013). Implicit Motives, Leadership, and Follower Outcomes: An Empirical Test of CEOs. *Journal of Leadership & Organizational Studies*, 20(1), 7–24. https://doi.org/10.1177/1548051812467207
[19] Steele & Plenty (2015). Supervisor-Subordinate Communication Competence and Job and Communication Satisfaction. *International Journal of Business Communication*. 52(3), 294-318. https://doi.org/10.1177/2329488414525450
[20] Martin, S.; Liao, H.; Campbell, E. (2013). Directive versus Empowering Leadership: A Field Experiment Comparing Impacts on Task Proficiency and Proactivity. *Academy of Management Review*, 56(5), 1372-1395. https://doi.org/10.5465/amj.2011.0113
[21] Scudder, J. & Guinan, P. (1989). Communication Competencies as Discriminators of Superiors' Ratings of Employee Performance. *Journal of Business Communication*, 26(3), 217-229. https://doi.org/10.1177/002194368902600302
[22] Mayfield, J. & Mayfield, M. (2012). The Relationship Between Leader motivating Language and Self-Efficacy: A Partial Least Squares Model Analysis. *Journal of Business Communication*, 49(4), 357-376. https://doi.org/10.1177/0021943612456036
[23] Min, C. & Schirmer, A. (2011). Perceiving verbal and vocal emotions in a second language. *Cognition and Emotion*, 25(8), 1376-1392. https://doi.org/10.1080/02699931.2010.544865
[24] Douglas, C.; Martin, J.; Krapels, R. (2006): Communication in the Transition to Self-Directed Work Teams. *Journal of Business Communication*, 43(4), 295-321. https://doi.org/10.1177/0021943606291704
[25] Sullivan, J. (1988). Three Roles of Language in Motivation Theory. *Academy of Management Review*, 13(1), 104-115.
[26] Delbecq, A.; House, R.; de Luque, M.S.; Quigley, N. (2013). Implicit Motives, Leadership, and Follower Outcomes: An Empirical Test of CEOs. *Journal of Leadership & Organizational Studies*, 20(1), 7–24. https://doi.org/10.1177/1548051812467207
[27] Owens, B. & Hekman, D. (2012). Modeling how to Grow: an Inductive Examination of Humble Leader Behaviors, Contingencies, and Outcomes. *Academy of Management Journal*, 55(4), 787-818. https://doi.org/10.5465/amj.2010.0441
[28] Hartley, P. (1999). *Interpersonal Communication*. Routledge, USA.
[29] Rayudu, C.S. (2010). *Communication*. Himalaya Publishing House, Mumbai, 2010.
[30] Juholin, E. (2001). *communicare*! Inforviestintä Oy.
[31] Kets de Vries, M. (2001). *The Leadership Mystique*. A User's manual For the Human Enterprise. Pearson Education Limited. The Great Britain.
[32] Delbecq, A.; House, R.; de Luque, M.S.; Quigley, N. (2013). Implicit Motives, Leadership, and Follower Outcomes: An Empirical Test of CEOs. *Journal of Leadership & Organizational Studies*, 20(1), 7–24. https://doi.org/10.1177/1548051812467207
[33] Nederström, M. & Niitamo, P. (2010). *Construction and Validation of a Work Personality Inventory*. Helsinki University of Technology, Department of Industrial Engineering and Management, Report 1.

[34] Mayfield, J. & Mayfield, M. (2012). The Relationship Between Leader motivating Language and Self-Efficacy: A Partial Least Squares Model Analysis. *Journal of Business Communication*, 49(4), 357-376. https://doi.org/10.1177/0021943612456036
[35] Delbecq, A.; House, R.; de Luque, M.S.; Quigley, N. (2013). Implicit Motives, Leadership, and Follower Outcomes: An Empirical Test of CEOs. *Journal of Leadership & Organizational Studies*, 20(1), 7–24. https://doi.org/10.1177/1548051812467207
[36] Owens, B. & Hekman, D. (2012). Modeling how to Grow: an Inductive Examination of Humble Leader Behaviors, Contingencies, and Outcomes. *Academy of Management Journal*, 55(4), 787-818. https://doi.org/10.5465/amj.2010.0441
[37] Avey, J. B., Avolio, B. J., & Luthans, F. (2011). Experimentally analyzing the impact of leader positivity on follower positivity and performance. *The Leadership Quarterly*, 22, 282-294. https://doi.org/10.1016/j.leaqua.2011.02.004
[38] Kelloway, E.; Weigand, H.; McKee, M.; Das, H. (2013). Positive Leadership and Employee Well-Being. *Journal of Leadership & Organizational Studies*, 20(1), 107-117. https://doi.org/10.1177/1548051812465892
[39] Avey, J. B., Avolio, B. J., & Luthans, F. (2011). Experimentally analyzing the impact of leader positivity on follower positivity and performance. *The Leadership Quarterly*, 22, 282-294. https://doi.org/10.1016/j.leaqua.2011.02.004
[40] Lappalainen, P. (2012). *Socially Competent Leadership – predictors, impacts and skilling in engineering*. Lappeenranta University of Technology, Dissertation Series 347.
[41] Martin, S.; Liao, H.; Campbell, E. (2013). Directive versus Empowering Leadership: A Field Experiment Comparing Impacts on Task Proficiency and Proactivity. *Academy of Management Review*, 56(5), 1372-1395. https://doi.org/10.5465/amj.2011.0113
[42] Jain, A. & Giga, S. (2011). Social power as a means of increasing personal and organizational effectiveness: The mediating role of organizational citizenship behavior. *Journal of Management and Organization*, 17, 412-432. https://doi.org/10.1017/S1833367200001553
[43] Gooty, J.; Connelly, S.; Griffith, J.; Gupta, A. (2010). "Leadership, affect and emotions: A state of the science review", *The Leadership Quarterly*, 21, 979-1004. https://doi.org/10.1016/j.leaqua.2010.10.005
[44] Fineman, S. (2003). *Understanding Emotion at Work*. London, Sage, 2003.
[45] Juuti, P. (2002). Puheenvuoroja johtamisen ja yrittämisen etiikasta (Translated by P.L.: On leadership and entrepreneurship ethics) Aavaranta-series no50.
[46] Fisher, C. (2000). Mood and emotions while working: missing pieces of job satisfaction? *Journal of Organizational Behavior*, 21, 185-202. https://doi.org/10.1002/(SICI)1099-1379(200003)21:2<185::AID-JOB34>3.0.CO;2-M
[47] Lappalainen, P. (2012). *Socially Competent Leadership – predictors, impacts and skilling in engineering*. Lappeenranta University of Technology, Dissertation Series 347.
[48] Judge, T.; Piccolo, R.; Kosalka, T. (2009). The bright and dark sides of leader traits: A review and theoretical extension of the leader trait paradigm. *Leadership Quarterly*, 20, 855-875. https://doi.org/10.1016/j.leaqua.2009.09.004
[49] van Hattum-Janssen, N & Mesquita, D. (2011). Teacher perception of professional skills in a project-led engineering semester. *European Journal of Engineering Education*, 36(5), 461-472. https://doi.org/10.1080/03043797.2011.606501
[50] Rouhiainen-Neunhäuserer, M. (2009). *Johtajan vuorovaikutusosaaminen ja sen kehittyminen* (Translated by P.L. Managerial interaction ability and its development). Jyväskylä University, Dissertation series.
[51] Bar-On, R. (2006). The Bar-On model of emotional-social intelligence (ESI). *Psicothema*, 18, 13-25.

[52] Nederström, M. & Niitamo, P. (2010). *Construction and Validation of a Work Personality Inventory*. Helsinki University of Technology, Department of Industrial Engineering and Management, Report 1.
[53] Christensen, J., Henriksen, L.B., Kolmos, A. (2006). Engineering Science, Skills, and Bildung. Aalborg University, Denmark. Published in A. Kolmos (Ed.): *Future Engineering Skills, Knowledge and Identity*.
[54] Rosch, M.; Caza, A. (2012). The Durable Effects of Short-Term Programs on Student Leadership Development. *Journal of Leadership Education*, 11(1), 28-48. https://doi.org/10.12806/V11/I1/RF2
[55] McAdams, D. & Pals, J. (2006). A New Big Five. Fundamental Principles for an Integrative Science of Personality. *American Psychologist*, 61(3), 204-217. https://doi.org/10.1037/0003-066X.61.3.204
[56] Tejeda, M.; Scandura, T.; Pillai, R. (2001). The MLQ Revisited. The Psychometric properties and recommendations. *The Leadership Quarterly*, 12(1), 31-52. https://doi.org/10.1016/S1048-9843(01)00063-7
[57] Hammer, M; Champy, J. (2001). *Reengineering the corporation*. A manifesto for business revolution. Nicholas Brealey publishing, London.
[58] Nederström, M. & Niitamo, P. (2010). *Construction and Validation of a Work Personality Inventory*. Helsinki University of Technology, Department of Industrial Engineering and Management, Report 1.
[59] Emilsson, U.M. & Lilje, B. (2008). Training social competence in engineering education: necessary, possible or not even desirable? An explorative study from a surveying education programme. *European Journal of Engineering Education*, 33(3), 259-269. https://doi.org/10.1080/03043790802088376
[60] Nederström, M. & Niitamo, P. (2010). *Construction and Validation of a Work Personality Inventory*. Helsinki University of Technology, Department of Industrial Engineering and Management, Report 1.
[61] Hartley, P. (1999). *Interpersonal Communication*. Routledge, USA.
[62] Mumford, M. & van Doorn, J. (2001). The Leadership of Pragmatism, Rethinking Franklin in the Age of Charisma. *The Leadership Quarterly*, 12, 279-309. https://doi.org/10.1016/S1048-9843(01)00080-7
[63] Ronen, S. & Mikulincer, M. (2012). Predicting employees' satisfaction and burnout from managers' attachment and caregiving orientations. *European Journal of Work and Organizational Psychology*, 21(6), 828-849. https://doi.org/10.1080/1359432X.2011.595561
[64] Dashborough, M.; Ashkanasy, N.; Tee, E.; Tse, H. (2009). What goes around comes around: How meso-level negative emotional contagion can ultimately determine organizational attitudes toward leaders. The *Leadership Quarterly*, 20(4), 571-585. https://doi.org/10.1016/j.leaqua.2009.04.009
[65] Bar-On, R. (2006). The Bar-On model of emotional-social intelligence (ESI). *Psicothema*, 18, 13-25.
[66] Douglas, C.; Martin, J.; Krapels, R. (2006): Communication in the Transition to Self-Directed Work Teams. *Journal of Business Communication*, 43(4), 295-321. https://doi.org/10.1177/0021943606291704
[67] Goleman, D. & Boyatzis. (2008). Social Intelligence and the Biology of Leadership. *Harvard Business Review*, Sept, 74-81.
[68] Lehmann, M.; Christensen, P.; Du,X.; Thrane, M. (2008). Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. *European Journal of Engineering Education*, 33(3), 283-295. https://doi.org/10.1080/03043790802088566

[69] Niitamo, P. (2011). Intercultural Work Competence. Published in Lappalainen, P. (Ed.) It's just People with People – Views of Social Responsibility. *Aalto University Crossover Publication Series*, 1/2011, 39-45.
[70] Paeilla, A.; Hogan, R.; Kaiser, R. (2007). The toxic triangle: Destructive leaders, susceptible followers, and conducive environments. *The Leadership Quarterly*, 18(3), 176-194. https://doi.org/10.1016/j.leaqua.2007.03.001
[71] Nederström, M. & Niitamo, P. (2010). *Construction and Validation of a Work Personality Inventory*. Helsinki University of Technology, Department of Industrial Engineering and Management, Report 1.
[72] Lappalainen, P. (2012). *Socially Competent Leadership – predictors, impacts and skilling in engineering*. Lappeenranta University of Technology, Dissertation Series 347.

7 Author

Pia Lappalainen, D.Sc (Tech) and MA (English and French philology, pedagogics and communications), is a researcher in the field of organizations and management. She investigates pedagogy for teaching leadership to engineers at Aalto University, Finland, where she works as a lecturer.

8 Appendix

Factor analysis based on respondents with no managerial experience.

		Rotated Component Matrix* / Component									
		1	2	3	4	5	6	7	8	9	10
1. EMOTIONAL STABILITY	M78. is reliable	,700									
	M58. tolerates failure and disappointments	,630									
	M57. remains calm and collected even in crises	,622									
	M70. apologizes when necessary	,609									
	M69. myöntää virheensä / admits his/her mistakes	,603									
	M77. is balanced and at peace with him/herself	,565		,454							
	M27. keep others up-to-date and shares information	,536									
	M79.is emotionally intelligent	,514	,427								
	M48. is flexible, capable of compromising	,512									
	M18. is not impulsive or easily provoked	,483									

	M74. tolerates and respects diversity	,480									
	M23. communi-cates negative issues face-to-face	,471									
	M72. takes responsibility for others and their wellbeing	,463									
	M17. takes responsibility for the atmosphere	,460									
	M22. is collegial and expresses solidarity	,456									
	M44. likes to help others	,450									
	M39. is realistic and considers facts	,443									
	M41. is self-aware and realistic about him/herself	,441									
	M33. is a good listener	,432									
	M42. recognizes his/her flaws and weaknesses	,426									
	M20. doesn't avoid emotional situations	,413									
2. AGREEABLENESS	M10. expresses emotions		,720								
	M7. expresses empathy		,664								
	M16. hugs or touches in emotional situations		,647								
	M8. discusses issues outside work		,638								
	M76. is warm and agreeable	,462	,571								
	M6. communi-cates in an original and personal style		,515								
	M49. has a sense of humor		,444								
	M56. is intuitive and relies on instinct		,440								
	M25. is sensitive to other people's moods		,416								
	M45. relies on others		,400								
3. SELF-LEADERSHIP	M66. wants to develop as a human being			,620							
	M71. takes responsibility for his/her wellbeing and self			,595							

	M65. is entrepre-neurial			,584							
	M63. is good at motivating him/herself			,569							
	M64. seems content and happy			,531							
	M40. believes in him/herself			,473							
	M67. does not compromise his/her values			,470							
	M46. willingly leads others										
	M73. is con-cerned for the environment and sustainability										
4. EFFICIENCY	M53. makes decisions in a speedy manner				,554						
AND ENERGY	M81. is energetic and enthusiastic				,523						
	M36. is competi-tive				,513						
	M32. is extra-verted and sociable				,510						
	M29. masters small-talk		,440		,509						
	M14. is an enthusiastic public performer				,496						
	M43. is assertive and decisive				,490						
	M26. negotiates skillfully				,472						
	M51. is efficient and a high achiever				,461						
	M80. is credible and convincing				,437						
	M61. is intelli-gent										
	M50. is goal-oriented and determined										
5. CONSCIENTIOUSNESS	M52. carefully considers every decision					,656					
	M54. is systemat-ic and organized					,635					
	M47. is compli-ant, follows advice and rules					,623					
	M30. focuses on detail					,621					
	M55. solves problems analytically					,567					
	M37. makes decisions based on fact					,503					
	M60. tolerates routines					,471					
	M59. is punctual					,432					

and a good time-manager										
M62. thinks critically										
M12. gives critical feedback						,779				
M13. accepts critical feedback						,735				
M11. gives positive feedback						,642				
M19. expresses opinions assertively						,490				
M15. inspires and motivates others										
M35. is willing to experiment with new ideas							,639			
M21. is inspired by new ideas and change							,637			
M34. is creative and innovate							,541			
M28. networks and participates actively							,438			
M38. is optimistic and hopeful							,429			
M75. adapts easily to change										
M4. has academic writing skills								,595		
M5. communicates clearly and unambiguously								,576		
M9. is good at summarizing								,576		
M3. has insight and visionariness								,478		
M31. focuses on the bigger picture										
M1. has theoretical domain expertise									,705	
M2. has practical, hands-on, field-related experience									,693	
M24. makes sure his/her messages are understood										
M68. is absolutely honest in every situation										,525

Extraction Method: Principal Component Analysis.

a. Rotation converged in 14 iterations.

Rotation Method: Varimax with Kaiser Normalization.

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