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Short Paper

Using Online Discussions to Develop the Entrepreneurial Mindset in Environmental Engineering Undergraduates: A Case Study

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Abstract—Entrepreneurship is an important aspect of the U.S. and global economy. As such, developing an entrepreneurial mindset is crucial for both engineering students and practicing engineers. The purpose of this paper is to investigate the role of online discussions, as a pedagogical approach, in the development of the entrepreneurial mindset. Online discussions prompts were developed using the Kern Engineering Entrepreneurial Network (KEEN) framework as a guide. The KEEN framework proposes an entrepreneurial mindset can be fostered in students by stimulating curiosity, strengthening connections, and creating value. This paper describes the methodology and rationale that served as the foundation for this exploratory study. Examples are provided for online discussion prompts developed and administered in two different environmental engineering undergraduate courses: Introduction to Environmental Engineering (three credit, undergraduate, online course offered during two different summer sessions) and Seminar in Environmental Engineering (one credit, undergraduate level, face-to-face course offered during one semester). Quantitative and qualitative methods were used to analyze and assess potential impacts of online discussion prompt use. The findings provide lessons learned for integrating the KEEN framework into undergraduate engineering courses through online discussions.

Keywords—Entrepreneurial mindset, online discussions, writing

1 Introduction

1.1 Motivation for the case study

The entrepreneurial mindset has been characterized as a "growth-oriented perspective through which individuals promote flexibility, creativity, continuous innovation, and renewal" [1]. Not only is the entrepreneurial mindset beneficial for establishing new companies, it is also essential to the vitality and growth of existing firms and or-

ganizations to foster competitiveness and survival. In recent years, promoting an entrepreneurial mindset in students has received acceptance and praise within the engineering education community [2-4]. In this domain, it is increasingly acknowledged that engineers need to improve upon, design and innovate new products and services with emphasis on the value to users, as opposed to the traditional engineering concepts associated with technical and functional performance features [5, 6]. This is true whether they choose to work in startups or existing organizations. Engineering students themselves also recognize the potential value of entrepreneurship knowledge to their career prospects and choices [7, 8]. Given these realities, engineering faculty and administrators are placing a greater focus on disseminating resources to assist engineering faculty in fostering the entrepreneurial mindset into existing engineering courses [9, 10].

1.2 Importance of stakeholder feedback

In spring 2015, the authors conducted exploratory research to understand the potential needs and benefits associated with fostering an entrepreneurial mindset among engineering students. The authors developed a survey and collected data from industry representatives (n = 19), engineering faculty (n = 21), and engineering students (n = 363). The survey asked participants to reflect on the different categories of entrepreneurially-minded skills being sought by employers. In addition, the survey asked participants to consider what categories of entrepreneurially-minded skill development should be offered in engineering classrooms. A student focus group was also conducted with seven undergraduate engineering students with the overall goal to assess interest and awareness related to entrepreneurship skills and the entrepreneurial mindset, while also identifying challenges to engaging students in associated extra-curricular activities and events. Results from the survey and focus group highlighted the need to incorporate mindset activities at every level of the engineering curriculum, not just senior design courses [11, 12].

There are many different formats, pedagogical approaches, and opportunity for engineering students to seek out entrepreneurial skillsets, such as:

- Capstone design courses
- Design-based "traditional" engineering courses
- Entrepreneurially-focused extra-curricular activities
- Enrolling in minors or badge programs with an entrepreneurship and/or innovation emphasis

However, from a faculty perspective, some engineering educators find it difficult to add yet another topic into rigorous and content-filled engineering courses. In response, a group of faculty decided to conduct an exploratory approach to determine a pedagogical approach to optimize teaching effectiveness and efficiency related to incorporating the entrepreneurial mindset into traditional engineering courses. Online discussions were chosen as the faculty group believed this pedagogical approach provided an ideal start for incorporating the entrepreneurial mindset into undergraduate engineering curriculum; regardless of whether the course is online or face-to-face, online discussions

offer ease in implementation without taking away from the rigor associated with engineering content.

1.3 Research objectives

This case study offers engineering educators insight into one approach for incorporating the entrepreneurial mindset into the engineering classroom with limited disruption to in-class lecture and activities. The objectives of this paper are twofold. First, the paper will provide examples of discussion prompts deployed in two different environmental engineering classrooms, including lessons learned and engineering educator tips for deploying online discussions. Second, the paper will describe evaluation techniques used in an attempt to assess student learning, including student self-reported perceptions related to student learning inside and outside the classroom, and student self-reported perceptions related to components of the entrepreneurial mindset. The study will be guided by the following research questions:

- What is the role of online discussions, as a pedagogical approach, in the development of the entrepreneurial mindset?
- How can student learning be assessed to evaluate the effectiveness of online discussions developed within the context of the entrepreneurial mindset?

The overall intent is to show how discussion prompts can be used as a tool to promote practice and development of the entrepreneurial mindset. The next section, Background, will provide an overview of innovation and entrepreneurship frameworks. The Methods section will describe the two environmental engineering courses impacted, the discussion prompts developed and deployed, and an explanation of the analysis methods. The Analysis and Results section will provide a summary of the results, including both quantitative and qualitative findings. The Discussion and Implications section will provide major project takeaways with particular emphasis on the relevance and importance for engineering education, and recommendations for future classroom implementations. The final section, Conclusions and Future Work, will provide a holistic perspective of the manuscript, stating limitations, highlighting the motivation, and suggesting recommendations or future research.

2 Background

2.1 Overview of Innovation and Entrepreneurship Frameworks [13]

We drew on several existing innovation and entrepreneurship frameworks that address the behaviors, characteristics, skills, or attributes associated with the entrepreneurial mindset. Considering the insights offered through von Brocke et al. [14], it is important to note that the authors focused on frameworks commonly used by entrepreneurship engineering educators in the United States.

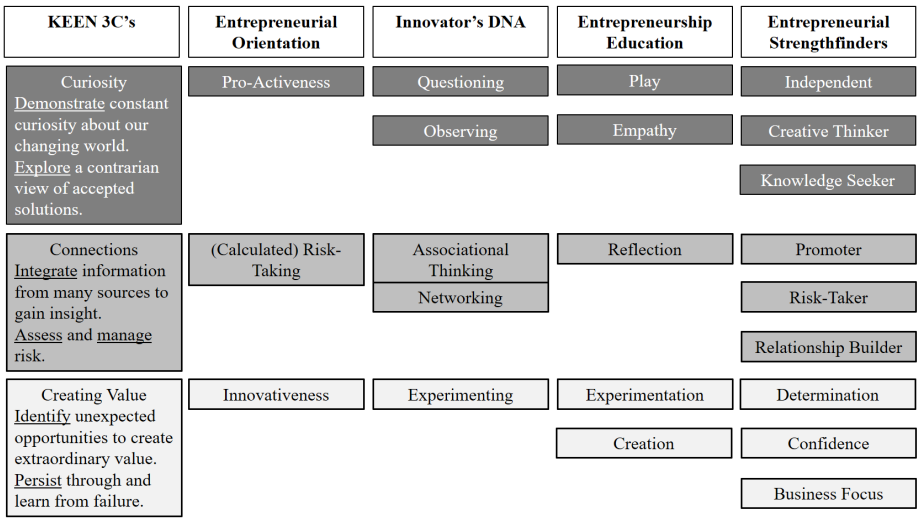

Fig. 1. Summary of Entrepreneurially-Minded Frameworks

The KEEN (Kern Entrepreneurial Engineering Network) framework [15] takes an anecdotal approach and proposes what are referred to as the 3C's of the entrepreneurial mindset:

- Curiosity (demonstrating constant curiosity about our changing world and exploring a contrarian view of accepted solutions)
- Connections (integrating information from many sources to gain insight, as well as assessing and managing risk)
- Creating Value (identifying unexpected opportunities to create extraordinary value and persisting through and learning from failure). The Entrepreneurial Orientation framework [16, 17] was the result of empirical research identifying pro-activeness, [calculated] risk-taking, and innovativeness as three critical characteristics for entrepreneurial mindsets. The Innovator's DNA, which resulted from a six-year study of entrepreneurs and executives [18], suggested that innovative entrepreneurs exhibit skills including associating, questioning, observing, experimenting, and networking. The book, "Teaching Entrepreneurship: A Practice Based Approach" [19], drew from years of experience training entrepreneurship educators and anecdotal evidence to posit that entrepreneurial orientation stems from practicing empathy, play, reflection, experimentation, and creation. Finally, the Entrepreneurial Strengthsfinder, which emerged from Gallup research [20], found that personality traits, including independent, creative thinker, promoter, knowledge-seeker, determination, confidence, risk-taker, relationship-builder, business focus, and delegator, were drivers of successful entrepreneurs.

These frameworks are summarized in Figure 1, which is toned in color to show the similarities across the frameworks. For example, KEEN's notion of Curiosity is conceptually similar to Pro-Activeness (from Entrepreneurial Orientation), Questioning

and Observing (from the Innovator's DNA), and Play and Empathy (from Entrepreneurship Education). Although there is similarity across the frameworks, for the purpose of this study, the KEEN framework was used due to its specific focus on undergraduate engineering education.

2.2 Introduction to the KEEN framework

The Kern Entrepreneurial Engineering Network (KEEN), an education-focused program, was developed with support from the Kern Family Foundation. KEEN is a group of about forty U.S. universities and includes hundreds of engineering faculty, with a mission as follows: "We are a national partnership of universities with the shared mission to graduate engineers with an entrepreneurial mindset so they can create personal, economic, and societal value through a lifetime of meaningful work." The KEEN framework is a guide which can be used to curate entrepreneurial minded learning curriculum for undergraduate engineering students. The intent of the framework is to develop student behaviors and attributes which focus more on preparing students to think and design strategically, rather than simply participating in society and the workforce as an "obedient engineer".

Several educational research investigations have explored the role of the KEEN framework. Huerta and colleagues [21] used introductory engineering design artifacts and written student reflections to conduct a thematic analysis; the findings revealed student awareness, intention and action towards facets related to the entrepreneurial mindset. A different study focused on humanities courses (at a primarily engineering university), integrating the KEEN student outcomes through the development of case studies and inquiry related to real-world engineering applications, to assist students in answer the age old question – *when will I ever use this?* Liu and authors [22] incorporated the KEEN framework into upper-level mechanical engineering courses including Mechatronics, Heat Transfer, and Fluid Mechanics; the results provide evidence and demonstration of behaviors associated with the entrepreneurial mindset when students participate in the three-course scaffold entrepreneurially-minded problem-based learning experience. Although, these efforts have proven fruitful, limited research has focused on integrating the entrepreneurial mindset through online discussions.

3 Methods

3.1 Participants, courses, and discussion prompt development

The project deployment was conducted at a medium-sized, private, inner city university in the Midwest region of the United States. Online discussion prompts, which focused on developing curiosity, connections and creating value, were developed and deployed in two different environmental engineering courses. The discussion prompts were developed to incorporate the KEEN framework. In particular, specific attention was given to promote building interest in technical topic areas, developing an entrepreneurial mindset in students, and improving learning general course learning outcomes.

This remainder of this section describes the details associated with the development and deployment of the discussion prompts. In both courses, participation in the discussion prompts was compulsory in that it counted towards the course grade.

Table 1 provides example discussion prompts developed for Introduction to Environmental Engineering. The course, offered as a 3-credit class, provides a vital yet fundamental foundation for understanding and evaluating the environment and related design systems with consideration for environmental quality control. The courses was delivered during two different 8-week summer sessions (2015 & 2016) using the online learning management system, D2L. This course is mandatory for all engineering undergraduates enrolled in the civil engineering bachelor's degree. The faculty member developed the prompts, in collaboration with an instructional designer, by incorporating the KEEN 3C's into common topics in environmental engineering, finding opportunities to focus on stimulating curiosity, strengthening connections, and creating value. The same faculty member instructed both undergraduate sessions; in total, twelve students enrolled in the class and participated in the discussions. The course enrollment numbers are typical for this course at this institution.

Table 1. Example Discussion Prompts: Introduction to Environmental Engineering [13]

1. Water Resources & Pollutants: Are we actually running out of water or not? Take a stand and support it with explanations regarding quantity, quality, and potential stressors. Pick one of the following proposals about alternative sources of fresh water and argue in support of or against the proposal. Be sure to do some research (online or otherwise) to gather related information and viewpoints. Describe the information and potential implications of your position. Additionally, address the concerns of those who take alternate positions and suggest potentially acceptable alternatives. - Investors propose to tow icebergs to the Middle East for use as drinking water supplies - The City of Waukesha proposes to pipe water from Lake Michigan to augment groundwater sources in the drinking water system - The county legislature in Texas proposes to use reclaimed water (treated wastewater) to irrigate cotton and corn fields - Citizens in Colorado propose to use rain barrels for outdoor watering purposes (e.g., lawns, flowers, car washing)
2. Water Treatment: Make the case that tap water or bottled water is a better choice based on safety, taste, economics and convenience of each. To inform your discussion, take a look online for information about tap water treatment and cost and look at the labels of a couple different brands of bottled water to find out where the water comes from and how it is treated.
3. Wastewater Treatment: (1) Antibiotics, endocrine disrupting compounds (EDCs), pharmaceuticals and personal care products (PPCPs), and nanoparticles are considered emerging problems in wastewater treatment. Take a position about whether or not any or all of these are a problem. Describe what is currently being done about them, if anything. (2) Based on your understanding of these issues, do you think measures should be taken to keep them out of water environments in the first place? If so, what would you recommend? Do you think there should be greater focus on removing them from wastewater? If so, what kinds of things do you think should be done? Is this much ado about nothing?

Table 2 showcases examples discussion prompts developed for the Seminar in Environmental Engineering, a one-credit course delivered in a face-to-face classroom, supplemented with online discussions using the D2L learning management system. The course was deployed during the fall 2016 semester. This course featured guest speakers addressing topics such as water and wastewater treatment, storm water management and urban hydrology, air pollution, and hazardous waste management. It was a pass-or-fail class using a "satisfactory" or "unsatisfactory" grading basis. Again, the faculty

member developed the prompts by incorporating the KEEN 3C's into common topics in environmental engineering, finding opportunities to focus on promoting curiosity, encouraging connections, and creating value. Each discussion session took place for one week, requiring students to upload an initial post and a response post (responding to a peer's initial post). Students were given a grading rubric identifying expectations associated with uploading both the initial post and response post. In total, five students enrolled in the class and participated in the discussions. The course enrollment numbers are typical for this course at this institution.

Table 2. Example Discussion Prompts: Seminar in Environmental Engineering

1. Triclosan: The speaker presented his research on removing triclosan from wastewater using biochar as an innovative adsorbent. He mentioned that the FDA (Food and Drug Administration) recently banned the use of triclosan in soap products (effective in 2017). Do you think that micropollutants should be banned in all products? Why or why not? Please consider the advantages and disadvantages of these chemicals in products, people, and the environment in your responses.
2. Biosolids: The solids generated during wastewater treatment contain the solid material removed during the processes. They also have a lot of organic content, which makes them perfect for anaerobic digestion, where methane can be produced while the solids are stabilized for ultimate disposal. The final solids also can contain valuable resources such as nutrients or harmful things such as metals or pathogens. In the US, biosolids are regulated for land application under EPA Rule 503, which focuses on metal and pathogen content (https://www.epa.gov/biosolids/frequent-questions-about-biosolids). In some countries, e.g., many parts of Europe, biosolids can't be land applied, and are instead incinerated or landfilled. How do you feel about the use of biosolids for land application? Furthermore, how do you feel about biosolids-derived products such as the struvite that the speakers talked about removing? Does it have value as a fertilizer and do regulations need to shift to address this? Do you generally feel that regulations reflect the current times or do they lag behind or lead into the future?
3. Holistic Approach: "Be comfortable with being uncomfortable." This is a sentiment that the Dean promotes in her vision for engineering. The speaker echoed this in his advice at the end of the talk. Reflect on this sentiment. Do you agree or disagree? What does it mean to you? It the case of the Kinnickinnic River Watershed restoration project, one aspect of this "working outside your comfort zone" approach was to work with people/agencies/groups who you don't typically work with to take a more holistic approach to engineering projects. How can you enhance your ability to do this in your professional career? What changes in engineering curriculum would facilitate this approach?

3.2 Description of assessment methods [13]

The open-ended questions and the first two scale questions explored student perceptions related to learning outcomes. The latter four scale questions explore student perceptions related to the entrepreneurial mindset, as defined not only by the KEEN framework but also by other typically recognized frameworks. For example, "Formulating questions and generating own inquiries" is similar to the Innovator's DNA [18] Questioning and Associating, the Knowledge-seeker attribute of the Entrepreneurial Strengthsfinder [20], the Reflection aspect of the "Teaching Entrepreneurship: A Practice Based Approach" [19], and promoting Curiosity within the KEEN framework. As

another example, "Exploring alternatives" is similar to Experimenting in the Innovator's DNA [18] and "Teaching Entrepreneurship: A Practice Based Approach" [19], as well as promoting Curiosity in the KEEN framework. Yet, another example, "Encouraging and understanding diverse perspectives" is comparable to Empathy in "Teaching Entrepreneurship: A Practice Based Approach" [19] and encouraging Connections in the KEEN framework.

Open-Ended Questions (Both Pre- and Post-Assessment)

1. Identify the top three factors that are most important for student learning and success.
2. Blended learning occurs when a student learns at least in part through digital and online engagement with some element of student control over time, place, path, or pace. What is your perception of blended learning in comparison to face-to-face learning?
3. How might you further your skills/knowledge after this class is over?

Scaled Comparison (Only Post-Assessment)

In comparison to other courses, how much has your coursework in this course emphasized the following? (5 = Very Much; 1 = Not at All)

- Applying learning in new contexts
- Learning beyond the curriculum
- Formulating questions and generating own inquiries
- Exploring alternatives
- Encouraging diverse perspectives
- Understanding diverse perspectives

Fig. 2. IRB Approved Pre- and Post-Survey [13]

3.3 Introduction to case study analysis

A pre- and post- survey was developed by the researchers, approved by the Institutional Review Board, and administered to participants to investigate the research question. A summary of the pre- and post-survey is provided in Figure 2. Through an exploratory case study research design approach, the researchers examined all data sources in an attempt to understand the phenomenon under investigation; a benefit of case study approach is that investigators and researchers are able to obtain a holistic understanding of the phenomenon being considered as a result of multiple data sources [6, 23-25]. For this study, the surveys assisted researchers with developing a greater awareness of participant's behaviors, skills, and intentions towards the entrepreneurial mindset.

4 Analysis and Results

4.1 Qualitative analysis of open-ended questions (Pre- and Post-Surveys)

Results for the qualitative open-ended questions are presented here. Question 1 asked participants to identify factors important for student success and learning. Several responses were common for both the pre- and post-survey. Example responses include course schedule, student study habits, and teacher effectiveness. In general, participant responses offered limited change from pre- to post-survey.

Question 2 asked participants to share their perceptions of blended learning (online components AND face-to-face interactions) in contrast to face-to-face learning. In comparing pre- to post-survey results, the participant responses were substantially different. In the pre-survey, only 15% of the students stated that they preferred blending learning over face-to-face learning. However, in the post-survey, 50% of the students preferred blended learning over face-to-face learning. This large percentage increase implies that students perceive blended learning (integrating online discussions into the face-to-face classroom) as a worthwhile pedagogical approach for students to meet learning objectives.

Table 3. Example Pre- and Post-Survey Responses [13]

Example Pre-Survey Responses	Example Post-Survey Responses
- "I might review the lecture notes and read related books." - "Ensuring that I read through the chapter and possibly do extra problems to get more practice." - "Office hours with the teacher. Outside the realm of the teacher, I would go to a library to understand concepts."	- "Continue to keep up with current events involving Environmental Chemistry and its systems." - "Read more news articles on science as opposed to sports." - "Continue to keep up with the latest research and development in wastewater and drinking water treatment."

Question 3 ask participants to consider how they might further their knowledge and skill development outside the classroom upon completion of the course. In comparing pre- to post-survey results, the participant responses were substantially different, as shown in Table 3. In the pre-survey, participant responses focused on resources which were either provided by the faculty instructor or offered within the university. Yet, in the post-survey, participant responses focused on the individual's capacity to keep up with real-world events, news, trends, and research to further develop their skills and knowledge. This change in perspective implies that online discussions offer students life-long learning skills re-enforcing their ability to further improve their skills outside the classroom, with limited support from instructors and the university.

4.2 Quantitative analysis of scaled survey [13]

Table 4 provides the quantitative post-survey results. The participants responded to the following statement: "In comparison to other courses, how much has your coursework in this course emphasized the following? (1 = Not at All; 5 = Very Much)" [13].

Table 4. Results [13] - Student Perceptions of Discussion Assignment

Emphasis Area	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Avg
1. Applying learning in new contexts	5	4	5	4	5	5	4	4	5	4	4.5
2. Learning beyond the curriculum	5	4	5	4	4	5	4	5	5	5	4.6
3. Formulating questions and generating own inquiries	5	5	5	5	4	5	4	4	4	4	4.5
4. Exploring alternatives	5	4	5	4	3	5	5	4	4	5	4.4
5. Encouraging diverse perspectives	4	4	4	5	4	5	5	5	5	5	4.6
6. Understanding diverse perspectives	5	4	4	4	5	5	4	4	4	4	4.3

The average scores are all relatively high, however, *learning beyond the curriculum* and *encouraging diverse perspectives* received the highest scores. The initial two items (*applying learning in new contexts* and *learning beyond the curriculum*) focus on the student learning outcomes. The high scores imply the online discussions were effective pedagogical approach to attain student learning outcomes, particularly with *learning beyond the curriculum*. The last four items (*formulating questions and generating own inquiries*, *exploring alternatives*, *encouraging diverse perspectives*, *understanding diverse perspective*) focus on aspects associated with developing the entrepreneurial mindset, especially with *encouraging diverse perspectives*. In general, the high scores across all statements suggest that from a student's perspective, the KEEN-focused online discussions were effective in developing personality traits, behaviors, and skills previously linked to the development of the entrepreneurial mindset.

5 Discussion and Implications

5.1 Discussion and insights

The intent of this study was to explore the benefits of integrating the KEEN framework into two different Environmental Engineering courses.

There were two major findings related to this qualitative survey. First, the percent of students who preferred blended learning increased from 15% (before the entrepreneurially-minded discussions) to 50% (after the entrepreneurially-minded discussions). This implies that blended learning, and specifically entrepreneurially-minded online discussions, provide an ideal pedagogical approach to integrate the entrepreneurial mindset into the classroom. With respect to the research question, *What is the role of online discussions, as a pedagogical approach, in the development of the entrepreneurial mindset?*, entrepreneurially-minded online discussions were looked on favorable by the students. Second, in comparing Q3 (how to further knowledge acquisition) pre- to post-assessment, the findings suggest that students gained awareness and recognition towards online discussions as a viable option to further skills outside the classroom while simultaneously improving learning outcomes. Thus, with respect to the research question, *What is the role of online discussions, as a pedagogical approach, in the development of the entrepreneurial mindset?* Students perceived entrepreneurially-minded inquiry through information literacy, synthesis, and online research, as a method to further their knowledge outside the classroom.

With respect to the quantitative survey, the results suggest that from a student's perspective, the entrepreneurially-minded online discussions were effective in developing outcomes, behaviors, characteristics and skills previously linked to the entrepreneurial mindset. When considering the research question, *How can student learning be assessed to evaluate the effectiveness of online discussions developed within the context of the entrepreneurial mindset?* These findings imply that student self-reports are one approach to assessing effectiveness towards a learning outcome.

In summary, this case study provided examples of discussion prompts deployed in two different environment engineering classrooms. This provides evidence that writing assignments can easily be implemented into engineering courses without losing the rigor. Furthermore, based on instructor observation, students appeared better prepared for participation in classroom lecture. In that sense, online discussions can be viewed as an effective and efficient method for increasing student engagement in classroom activities with limited upfront work required by students. The connection to real-world principles allowed to the students to understand the practical purpose of classroom topics prior to understanding the theoretical importance offered through classroom lecture. This case study also provided examples of evaluation techniques applied in an attempt to assess student learning. These assessment techniques included student self-reported perceptions related to student learning inside and outside the classroom and student self-reported perceptions related to components of the entrepreneurial mindset. Although the evidence of attainment towards the entrepreneurial mindset is somewhat inconclusive, assessment practices are important and necessary components for obtaining and maintaining academic accreditation.

5.2 Recommendations for deploying online discussions

A large quantity of guidelines, best practices, and resources for facilitating online discussions can be found in the literature and through Centers for Teaching and Learning located on many university websites [26-28]. However, a number of key recommendations based on instructor feedback are provided here. These suggestions center on effectively and efficiently designing, managing, and assessing online discussions, optimizing minimal time investment and maximum student feedback.

First and foremost, it is important to clarify expectations at the beginning of the semester. This is true for both instructor expectations and student expectations. As an example, it is beneficial for the instructor to identify when he or she plans to read and provide feedback within the online discussion. This means being specific about what days and times during the week the instructor plans to access the discussion (e.g., M-F, 8-9 a.m.). Thus, students will know when [and when not] to expect instructor feedback. In the case of online discussions being deployed in large classes, instructors might find it helpful to assign student discussion leaders to help encourage timely and appropriate discussions. With respect to providing clarity for student expectations, a rubric is key [29, 30]. A rubric not only attests to the quality expected within the discussion, but also provides requirements for minimum quantity of initial posts and response posts. Furthermore, instructor anecdotal evidence suggests that setting a weekly routine is very

beneficial for the student. For example, the instructor might require students to provide an initial post weekly by Wednesdays and provide response posts weekly by Saturday.

6 Conclusion and Future Work

6.1 Summary

This study provided examples of discussion prompts deployed in two different environmental engineering classrooms: Introduction to Environmental Engineering and Seminar in Environmental Engineering. In addition, lessons learned and educator tips are offered to assist other educators in implementing similar types of curriculum. The case study described a variety of evaluation techniques used in an attempt to assess student learning including student self-reported perceptions related to student learning inside and outside the classroom and student self-reported perceptions related to components of the entrepreneurial mindset. This case study offered engineering educators insight into one approach for infusing the entrepreneurial mindset into the undergraduate engineering classroom. One benefit of this particular approach, using online discussion prompts, is that it afforded limited disruption to in-class lecture and activities.

6.2 Problems and challenges addressed

The entrepreneurial mindset, although useful for creating a new company, is also essential to the growth and vitality of existing organizations to ensure competitiveness and survival. It is increasingly acknowledged that engineers need to improve upon, innovate, and design new products and services with emphasis on the value to users, as opposed to the traditional engineering concepts associated with technical and functional features [5, 6]. University administrators and engineering faculty, alike, are placing a greater focus on disseminating resources to assist engineering faculty in fostering the entrepreneurial mindset in existing engineering courses [9, 10]. However, some engineering educators find it difficult to add yet another topic into rigorous and content-filled engineering courses. This case study provided the results of one approach to do this, using online discussion prompts, showing relevance in two different environmental engineering courses.

6.3 Value associated with the study

Data shows that discussion prompts can be an effective pedagogical tool in online courses. This paper describes their role and gives examples of how they are developed, which can be applied to any engineering course and/or discipline. Developing, facilitating, and assessing online discussions can be done efficiently and effectively with a somewhat minor instructor time investment prior to offering the course [13, 31-34], and with limited disruption to the classroom. Moreover, online discussions deliver several benefits to the instructor and students when integrated into face-to-face classrooms and/or online course environments [35-37]. First, online discussions afford students the

essential and indispensable time to create thought provoking responses, encouraging students to consider additional news, events, trends, and research to support their discussion posts. Second, they provide students the potential to gain additional insights and perspectives through reading and responding to other students' posts. Third, online discussions offer instructors the ability to deliver immediate feedback to students and ask additional questions to provide depth into the discussion subject. Finally, while not exclusive to entrepreneurship, it appears this approach to reflection and online discussion fosters qualities in students that are echoed in entrepreneurial frameworks; qualities that are not simply limited to the KEEN framework but across multiple entrepreneurial frameworks. This exploratory analysis offers insight into the budding implications of the activities the KEEN initiative is promoting, specifically promoting the entrepreneurial mindset in undergraduate engineering students.

6.4 Recommendations for future work

It is important to note potential limitations of the study. First, the small class sizes, although typical of this institution, may limit the generalizability of the results. Additionally, the study was deployed through the D2L learning management system, where the ease of use for online discussions is different from other learning management systems. Lastly, the study developed online discussions for use in two environmental engineering courses. Thus, future related research should be conducted to further validate the study with respect to reliability and repeatability; this could be done by implementing entrepreneurially minded discussions with more students and classes (e.g., increase the sample size), across various engineering courses, and implemented in different learning management systems. Furthermore, future work should continue to investigate how discussion prompts and writing prompts can be used more extensively, how the prompts can be more interactive, and what rubrics can be developed to assess learning as well as engagement and motivation. This pedagogical approach can be valuable to educators faced with developing online courses and educators looking to make their class more practical without detracting from the rigor of the material.

7 References

[1] Ireland, R.D., M.A. Hitt, and D.G. Sirmon, a Model of Strategic Entrepreneurship: The Construct and its Dimensions. Journal of Management, 2003. 29(6): p. 963-989. https://doi.org/10.1016/s0149-2063_03_00086-2

[2] Byers, T., T. Seelig, S. Sheppard, and P. Weilerstein, Entrepreneurship: Its role in engineering education. The Bridge, 2013. 43(2): p. 35-40.

[3] Holzmann, P., E. Hartlieb, and M. Roth, From Engineer to Entrepreneur-Entrepreneurship Education for Engineering Students: The Case of the Entrepreneurial Campus Villach. International Journal of Engineering Pedagogy (iJEP), 2018. 8(3): p. 28-39. https://doi.org/10.3991/ijep.v8i3.7942

[4] Lepuschitz, W., G. Koppensteiner, U. Leeb-Bracher, K. Hollnsteiner, and M. Merdan, Educational Practices for Improvement of Entrepreneurial Skills at Secondary School Level. International Journal of Engineering Pedagogy (iJEP), 2018. 8(2): p. 101-114. https://doi.org/10.3991/ijep.v8i2.8141

[5] Zafoschnig, A. The development of the new ING-PAED IGIP curriculum into an umbrella for modularised national and regional engineering education curricula. in Interactive Collaborative Learning (ICL), 2013 International Conference on. 2013. IEEE. https://doi.org/10.1109/icl.2013.6644575
[6] Utesch, M.C., V. Seifert, L. Prifti, R. Heininger, and H. Krcmar. The Playful Approach to Teaching How to Program: Evidence by a Case Study. in International Conference on Interactive Collaborative Learning. 2017. Springer. https://doi.org/10.1109/educon.2017.7942846
[7] Duval-Couetil, N., T. Reed-Rhoads, and S. Haghighi, The Engineering Entrepreneurship Survey: An Assessment Instrument to Examine Engineering Student Involvement in Entrepreneurship Education. Journal of Engineering Entrepreneurship, 2011. 2(2). https://doi.org/10.1109/fie.2010.5673411
[8] Wheadon, J. and N. Duval-Couetil, Elements of entrepreneurially minded learning: KEEN white paper. The Journal of Engineering Entrepreneurship, 2016(7(3)): p. 17-25.
[9] Bosman, L. and S. Fernhaber, Teaching the entrepreneurial mindset to engineers. 2018, Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-61412-0_2
[10] Beiler, M.R.O., Integrating innovation and entrepreneurship principles into the civil engineering curriculum. Journal of Professional Issues in Engineering Education and Practice, 2015. 141(3). https://doi.org/10.1061/(asce)ei.1943-5541.0000233
[11] Duval-Couetil, N., E. Kisenwether, J. Tranquillo, and J. Wheadon, Exploring the Intersection of Entrepreneurship Education and ABET Accreditation Criteria. The Journal of Engineering Entrepreneurship, 2015. 6(2): p. 44-57. https://doi.org/10.7814/jeenv6n2p3
[12] Wilson, M.D., E. Holloway, and S.J. Gandhi. Entrepreneurship Education: Engineering a Pracademic Approach. in ASEE North Midwest Section Conference - Entreprenuership and Information Management. 2014. https://doi.org/10.17077/aseenmw2014.1038
[13] Bosman, L., B. Mayer, and P. McNamara. Promoting entreprenuerially minded learning through online discussions - curriculum innovation: incorporating the Kern Engineering Entrepreneurial Network (KEEN) framework into online discussions. in American Society of Engineering Education. 2017. Columbus, OH. https://doi.org/10.18260/1-2--28773
[14] Vom Brocke, J., A. Simons, B. Niehaves, K. Riemer, R. Plattfaut, and A. Cleven. Reconstructing the giant: On the importance of rigour in documenting the literature search process. in Ecis. 2009.
[15] KEEN. KEEN 3C's: Educational Outcomes. 2018; Available from: https://keenwarehouse.blob.core.windows.net/keen-downloads/KEEN_Framework_spread.pdf.
[16] Miller, D., The correlates of entrepreneurship in three types of firms. Management science, 1983. 29(7): p. 770-791. https://doi.org/10.1287/mnsc.29.7.770
[17] Covin, J.G. and D.P. Slevin, Strategic management of small firms in hostile and benign environments. Strategic management journal, 1989. 10(1): p. 75-87. https://doi.org/10.1002/smj.4250100107
[18] Dyer, J.H., H.B. Gregersen, and C.M. Christensen, The innovator's DNA. Harvard business review, 2009. 87(12): p. 60-67.
[19] Neck, H.M., P.G. Greene, and C.G. Brush, Teaching entrepreneurship: A practice-based approach. 2014: Edward Elgar Publishing.
[20] Clifton, J. and S. Bharadwaj-Badal, Entrepreneurial strengthsfinder. 2014.
[21] Huerta, M.V., J.S. London, A. Trowbridge, M.A. Avalos, W. Huang, and A.F. McKenna. Cultivating the entrepreneurial mindset through design: Insights from thematic analysis of first-year engineering students' reflections. in ASEE Annual Conference and Exposition, Conference Proceedings. 2017. https://doi.org/10.18260/1-2--28093
[22] Liu, L., J.A. Mynderse, A.L. Gerhart, and S. Arslan. Fostering the entrepreneurial mindset in the junior and senior mechanical engineering curriculum with a multi-course problem-

based learning experience. in Frontiers in Education Conference (FIE), 2015 IEEE. 2015. IEEE. https://doi.org/10.1109/fie.2015.7344040
[23] Creswell, J.W., Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research (3rd Edition). 2008: Upper Saddle River, NJ: Pearson.
[24] Yin, R.K., Case Study Research: Design and Methods (4th Edition). 2009: Applied Social Research Methods Series Vol 5. Thousand Oaks, CA: SAGE.
[25] Yin, R.K., Case study research: Design and methods (Fifth). 2014, London, UK: SAGE Publications Ltd.
[26] Rovai, A.P., Facilitating online discussions effectively. The Internet and Higher Education, 2007. 10(1): p. 77-88. https://doi.org/10.1016/j.iheduc.2006.10.001
[27] Collison, G., B. Elbaum, S. Haavind, and R. Tinker, Effective strategies for moderators. Quarterly Review of Distance Education, 2001. 2(4): p. 397-401.
[28] Hew, K.F. and W.S. Cheung, Attracting student participation in asynchronous online discussions: A case study of peer facilitation. Computers & Education, 2008. 51(3): p. 1111-1124. https://doi.org/10.1016/j.compedu.2007.11.002
[29] Larkin, T.L., A rubric to enrich student writing and understanding. International Journal of Engineering Pedagogy (iJEP), 2015. 5(2): p. 12-19. https://doi.org/10.3991/ijep.v5i2.4587
[30] Bodnar, C. and J. Kadlowec, Initial Validation of a Technical Writing Rubric for Engineering Design. International Journal of Engineering Pedagogy (iJEP), 2018. 8(1): p. 81-91. https://doi.org/10.3991/ijep.v8i1.7728
[31] Dunlap, J., Workload reduction in online courses: Getting some shuteye. International Society for Performance Improvement, 2005. May/June 2005. https://doi.org/10.1002/pfi.4140440507
[32] Shi, M., C.J. Bonk, and R.J. Magjuka, Time Management Strategies for Online Teaching. International Journal of Instructional Technology and Distance Learning, 2006. 3(2): p. 3-10.
[33] Kelly, R., Group work, discussion strategies to manage online instructor workload. Retrieved from www.facultyfocus.com, 2012.
[34] Bosman, L. and T. Zagenczyk, Revitalize your teaching: Creative approaches to applying social media in the classroom, in Social media tools and platforms in learning environments. 2011, Springer. p. 3-15. https://doi.org/10.1007/978-3-642-20392-3_1
[35] Zhu, E., Interaction and cognitive engagement: An analysis of four asynchronous online discussions. Instructional Science, 2006. 34(6): p. 451-480. https://doi.org/10.1007/s11251-006-0004-0
[36] Yang, Y.-T.C., A catalyst for teaching critical thinking in a large university class in Taiwan: asynchronous online discussions with the facilitation of teaching assistants. Educational Technology Research and Development, 2008. 56(3): p. 241-264. https://doi.org/10.1007/s11423-007-9054-5
[37] Ellis, R.A., 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, 2008. 18(3): p. 267-282. https://doi.org/10.1016/j.learninstruc.2007.06.001

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Developing an Industrial Engineering Study Plan Using ISM Approach

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Abstract—With the various developments that occur in the engineering field, it's necessary for academicians to develop appropriate curricula for engineering students. Being accredited from the Accreditation Board for Engineering and Technology (ABET) is an indication that an academic program has fulfilled international standards in engineering education. The main element in ABET evaluation process is Student Outcomes (SOs) as they incorporate several capabilities and skills expected by stakeholders such as employers. In this study, we used Interpretive Structural Modeling technique (ISM), which is a soft operational research technique, to prioritize SOs and develop a precise study plan for the Industrial Engineering program at Department of Industrial and Management Systems Engineering (IMSE) at Kuwait University (KU). This plan showed an intelligible depiction of the relationships between the SOs and a clear direction on how to merge them within the engineering study plan. For data collection, surveys were developed and conducted to faculty members at IMSE Department at KU in addition to a set of employers within the country. The results indicated that ISM model facilitates a clear understanding of the relationships among SOs within the Industrial Engineering study plan at IMSE at KU. In addition, it recommended that students should understand the professional and ethical responsibilities at early stages of the study plan and that should be followed by training them on effective communication techniques.

Keywords—Engineering education, study plan, ABET, ISM, prioritization, student outcomes, Industrial Engineering, curriculum

1 Introduction

Education is one of utmost importance for any country. Country's policies and strategic management efforts of both governmental and private organizations heavily depend on excellence in each and every sector, and engineering as of today continues to play one of the most vital roles in terms of education. A teaching program to raise generations of students will only be successful if there is a curriculum that is extensive yet collaborative with world standards, and innovative yet conforming to country's cultural needs. The Accreditation Board for Engineering and Technology (ABET) is playing the role of measuring these aspects to make sure that a teaching program remains satisfactory.

In this study, the Interpretive Structural Modeling (ISM) approach is employed to create a precise study plan for the Industrial Engineering program at the Industrial and Management Systems Engineering Department (IMSE) at Kuwait University. This study is unique in terms of ISM's application to include both the Kuwait University's faculty members and key personnel from Kuwait's business companies to determine and model the relationship between Student Outcomes (SOs) and what work should be done to obtain these outcomes. By doing so, a proper alignment of a broader range of constituents needs is assumed to be obtained while designing the designated program.

2 Previous Work

Much effort has been devoted to ways and methodologies to promote and sustain excellent education programs to train and raise today's engineers. ABET is playing a substantial role in this prospective. This section provides studies regarding ABET activities, its SOs and the presence of ABET standards in Kuwait. In addition, it provides some basic backgrounds about the ISM approach applied in the study.

2.1 ABET and accreditation in Kuwait

Student Outcomes assessment has been incorporated to institutions of higher education by government funding sources, industry, and academic accreditation entities such as ABET [1]. ABET is one of the programmatic accrediting organizations recognized by the U.S. Council for higher education accreditation since 1997, with the scope of accreditation that includes several program levels, ranging from associate to masters, in engineering, engineering technology, computing, and applied science in the United States and internationally [2], [3]. It was founded in 1932 as the Engineers' Council for Professional Development (ECPD), with activities driven by the professionals it served [2]. However, today's ABET standards for the accreditation process are provided by experts from 35 member societies by which it has accredited more than 3800 programs in 31 countries [2]. In addition to accrediting programs outside the USA, ABET has an international presence through its mutual recognition agree-

ments (MRA) and memoranda of understanding (MOU) with various international accrediting bodies [4].

Engineering programs that seek ABET accreditation are required to satisfy the following "eight criteria: students, program educational objectives, student outcomes (SOs), continuous improvement, curriculum, faculty, facilities, and institutional support" [5].

The accreditation journey takes around 20 months starting with a self-study report preparation by program seeking accreditation and ending by notifying the program with the accreditation action according to outcomes of the on-site visit conducted by the review team [6].

In Kuwait, there are 24 ABET accredited programs in five higher education institutes. Out of these accredited programs, 13 programs offer diploma degrees in various engineering technologies, 2 offer bachelor's degree in computer science, and 9 offer bachelor degrees in various engineering disciplines [7]. 8 of the engineering and one of the computer science accredited programs are offered at Kuwait University (KU). The KU engineering programs were initially accredited in 2006. The programs are Chemical Engineering, Civil Engineering, Computer Engineering, Electrical and Electronics Engineering, Engineering Management, Industrial Engineering, Mechanical Engineering, and Petroleum Engineering. The university was established in 1966 and has 17 colleges offering various graduate and undergraduate programs. All engineering programs are currently offered by the College of Engineering and Petroleum except the Computer Engineering program which is offered by the College of Computing Science and Engineering [8].

2.2 ABET student outcomes and curriculum design

Despite the effective impact of ABET accreditation criteria on improving quality of engineering education on continuous manner, third criterion related to student outcomes which defined in Table 1 plays a significant role in this regard. This criterion requires undergraduate engineering programs to meet program educational objectives through satisfying a predefined set of learning outcomes given in [5].

The student outcome assessment is the primary focus of higher education institutions to measure the results of their educational programs and courses [1]. Institutions cannot have comprehensive assessment processes within their organizations without laying down structures, policies, and procedures that encourage having coherent and cross-disciplinary collaboration curricula [1]. However, developing new curricula based on specifically identified learning objectives coupled with specific outcomes the achievement of which are assessed for continuous improvement will not have a significant impact on the institution unless its other parts are properly aligned [1]. In an effort to address this, researchers discussed various aspects related to curriculum design such as:

- Amount and distribution of design content when designing engineering curricula as compared to the amount of math, basic sciences, and engineering sciences content [9] & [10]

Table 1. Student Outcomes for Engineering Program

SOs	Explanations
A	An ability to apply knowledge of mathematics, science, and engineering
B	An ability to design and conduct experiments, as well as to analyze and interpret data
C	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D	An ability to function on multidisciplinary teams
E	An ability to identify, formulate, and solve engineering problems
F	An understanding of professional and ethical responsibility
g	An ability to communicate effectively
h	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i	A recognition of the need for, and an ability to engage in life-long learning
j	A knowledge of contemporary issues
k	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

- Methods to fulfill the multidisciplinary ABET requirement with multi-, inter- or trans – disciplinary capstone design courses [11]
- Roles of faculty members and students in ABET accreditation process especially those related to developing curriculums with impeded outcomes assessment setups [1] as well as implementation of planned strategies [12]
- Considering technology-based assessment, whenever appropriate, in order to mitigate the effect of time-intensive faculty involvement with students within the outcome- based learning setup and ensure having the outcome assessment as an inherent element in curriculum development [1]
- Addressing ABET SOs through learning objectives, instructional techniques, and assessment methods of individual courses of a certain program [12]
- Methods of teaching and assessing ABET "professional skills" (also known as soft skills) such as teamwork, understanding professionalism and ethics, communication, global and social context, lifelong learning, and knowledge of contemporary issues [13] & [14]
- Rating the importance of competencies represented within ABET SOs in the professional experience after completing an engineering undergraduate program [15]
- Integrating the "development of innovation competencies with regular engineering curriculum" to satisfy the increasingly demanded knowledge-sharing between research institutions and industry [16]
- Practices that enhance undergraduate engineering programs global preparedness [17]
- Proposing effective curriculum designs based on SOs prioritization in a way that incorporates the impeded relationships among them [18]

2.3 Interpretive structural modelling (ISM)

ISM is not a millennium or technological fashion to solve problems but is quite old and an extensively used model to approach decision problems, proposed firstly by J.

Warfield in 1973. All fundamental concepts, process to apply ISM as well as two illustrative examples may be found in [19]. The examples show how the complexity of a problem is handled by individual and group perceptions. As demonstrated by [20] in Fig 1, it is quite straightforward and easy to combine ISM with other problem solving techniques. It is a well-established methodology for identifying and summarizing relationships among specific elements, which define an issue or a problem. ISM transforms unclear, poorly articulated mental models of a system into visible well-defined, hierarchal models. Due to gradually used of the ISM methodology by various researchers, there are several studies that conducted to demonstrate the key concepts of the ISM in details [21].

ISM methodology is a proper method which used by researcher and industry manager to assist them to take optimum decisions. Likewise, there are other methods can be used for similar cases such as Analytic Hierarchy process (AHP) or Analytic Network Process (ANP). ISM involves a set of interconnected criteria, as well as it better match in this study than the other methods to address problems that are complex and subjective [22].

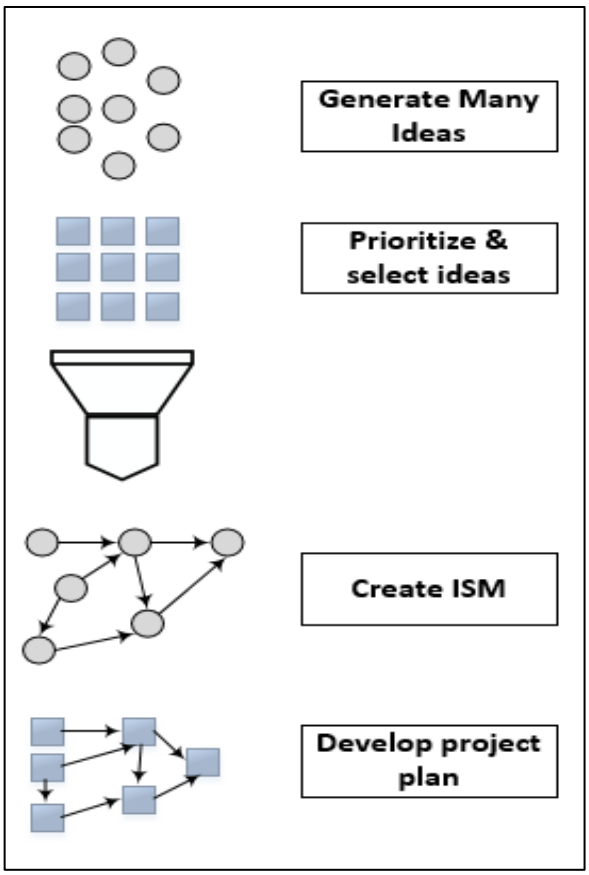

Fig. 1. High Level View of ISM Process (Adopted from:[20])

The ISM approach has been applied in various fields [23], [24], [25], [26] including education [27] and curriculum design [18]. In [27] ISM is used to examine the education system in India with the aim of prioritizing strategic issues in quality of education and freeing the education objectives from financial concerns, thus increasing effectiveness and accountability of education system.

In an effort to understand ABET SOs, listed in Table 1, and come up with effective curriculum designs, [18] used ISM to propose an ABET SOs prioritization scheme in a way that incorporates relationships among them. The study was conducted on an industrial engineering program at a Saudi University. The study showed the possibility of a systematic linkage between SOs and the curriculum while building the study plan systematically. The observed relationships among ABET SOs suggested exposing students to outcome (d) at an early stage while having them exposed to outcomes (b), (h), and (i) at the final stage of the study plan preceded directly by outcomes (j) and (f).

3 Scope, Methodology and Application

This study aims to develop a study plan of the Industrial Engineering program at IMSE Department at KU using the ISM method. In order to initiate the ISM methodology and articulate the SOs, first the Structural Self-Interaction Matrix (SSIM) of SOs is constructed by using the relationship types given in Table 2.

Table 2. Direction of the Relationships among SOs

Symbol	Direction of the Relationships Among the SOs (Explanation)
V	For the relation from SO (a) to SO (b) (i.e., factor a will influence factor b)
A	For the relation from SO (b) to SO (a) (i.e., factor a will be influenced by factor b)
X	For both direction relations (i.e., SOs (a) and (b) will influence each other)
O	For no relation between the SOs (i.e., SOs (a) and (b) are unrelated)

8 expert faculties from IE department in KU and 5 key personnel from Kuwait business companies have expressed their opinions using the SSIM as it is illustrated in Table 3 to obtain the initial reachability matrix of the SOs given in Table 4, after which final reachability matrix by taking into account the transitivity of SOs is obtained as it shown in Table 5.

Note that the driving power and dependence power of SOs are calculated as the sum of 1s in their corresponding rows and columns, respectively, and they are calculated after ensuring transitivity of the reachability matrix. Once the matrix is finalized, it is 'leveled' based on the previous steps in order to draw the corresponding directed graph and also build an ISM based study plan with SOs. Leveling process is performed by iterations. In each iteration, if an SO's reachability set is the same as the intersection set, then that SO is labeled with the corresponding level. Level I is shown in blue color in Table 6. After that, each labeled SO is removed from reachability set, antecedent set and intersection set to proceed with the next iteration. In the next iteration in our study, since this time SOs (d), (h) and (k) have their reachability sets as same as their intersection sets, they are labeled as Level II. In a similar manner, once

all SOs that have their reachability sets as same as their intersection sets, they are labeled until the ISM process is finished and the study plan is constructed based on annual delivery of the proposed study plan period.

Based on Table 6, SOs (a), (b), (c), (e), (i), and (j) are in Level I, SOs (d), (h), and (k) are in Level II, SO (g) is uniquely in Level III and SO (f) is uniquely in Level IV. Since all SOs are leveled at the end of iteration 4, the process is finalized.

Table 3. The Structural Self-Interaction Matrix (SSIM) Among SOs

	k	**j**	**i**	**h**	**g**	**f**	**e**	**d**	**c**	**b**	**a**
a	V	O	O	O	O	O	X	O	X	X	
b	A	O	O	O	O	O	X	O	V		
c	A	O	O	O	O	O	X	O			
d	O	O	O	O	V	V	O				
e	V	O	O	O	O	O					
f	O	O	O	O	O						
g	O	V	O	O							
h	O	V	O								
i	O	X									
j	O										
k											

Table 4. The Initial Reachability Matrix of SOs

Sos	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**	**(k)**
(a)	1	1	1	0	1	0	0	0	0	0	1
(b)	1	1	1	0	1	0	0	0	0	0	0
(c)	1	0	1	0	1	0	0	0	0	0	0
(d)	0	0	0	1	0	1	1	0	0	0	0
(e)	1	1	1	0	1	0	0	0	0	0	1
(f)	0	0	0	0	0	1	0	0	0	0	0
(g)	0	0	0	0	0	0	1	0	0	1	0
(h)	0	0	0	0	0	0	0	1	0	1	0
(i)	0	0	0	0	0	0	0	0	1	1	0
(j)	0	0	0	0	0	0	0	0	1	1	0
(k)	0	1	1	0	0	0	0	0	0	0	1

Table 5. Iterations of Labeling in ISM

SOs	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**	**(i)**	**(j)**	**(k)**	**Driving Power**
(a)	1	1	1	0	1	0	0	0	0	0	1	5
(b)	1	1	1	0	1	0	0	0	0	0	0	4
(c)	1	1*	1	0	1	0	0	0	0	0	1*	5
(d)	0	0	1*	1	0	1	1	0	0	0	0	4
(e)	1	1	1	0	1	0	0	0	0	0	1	5
(f)	0	0	1*	0	0	1	1*	0	0	0	0	3
(g)	0	0	0	0	0	0	1	0	0	1	0	2
(h)	0	0	0	0	0	0	0	1	0	1	0	2
(i)	0	0	0	0	0	0	0	0	1	1	0	2
(j)	0	0	0	0	0	0	0	0	1	1	0	2
(k)	1*	1	1	0	1*	0	0	0	0	0	1	5
Dependence Power	5	5	7	1	5	2	3	1	2	4	4	

Table 6. Iterations of Labeling in ISM

Iteration 1-Level I (blue)

Sos	Reachability Set	Antecedent Set	Intersection	Level
(a)	a,b,c,e,k	a,b,c,e,k	a,b,c,e,k	I
(b)	a,b,c,e,k	a,b,c,e,k	a,b,c,e,k	I
(c)	a,b,c,e,k	a,b,c,d,e,f,k	a,b,c,e,k	I
(d)	c,d,f,g	d	d	
(e)	a,b,c,e,k	a,b,c,e,k	a,b,c,e,k	I
(f)	c,f,g	d,f	f	
(g)	g,j	d,f,g	g	
(h)	h,j	h	h	
(i)	i,j	i,j	i,j	I
(j)	i,j	g,h,i,j	i,j	I
(k)	a,b,c,e,k	a,c,e,k	a,c,e,k	

Iteration 2-Level I crossed out and Level II (light pink)

Sos	Reachability Set	Antecedent Set	Intersection	Level
~~(a)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
~~(b)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
~~(c)~~	~~a,b,c,e,k~~	~~a,b,c,d,e,f,k~~	~~a,b,c,e,k~~	~~I~~
(d)	d,f,g	d	d	II
~~(e)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
(f)	f,g	d,f	f	
(g)	g	d,f,g	g	
(h)	h	h	h	II
~~(i)~~	~~i,j~~	~~i,j~~	~~i,j~~	~~I~~
~~(j)~~	~~i,j~~	~~g,h,i,j~~	~~i,j~~	~~I~~
(k)	k	k	k	II

Iteration 3- Level II crossed out and Level III (green)

Sos	Reachability Set	Antecedent Set	Intersection	Level
~~(a)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
~~(b)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
~~(c)~~	~~a,b,c,e,k~~	~~a,b,c,d,e,f,k~~	~~a,b,c,e,k~~	~~I~~
~~(d)~~	~~d,f,g~~	~~d~~	~~d~~	~~II~~
~~(e)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
(f)	f,g	f	f	
(g)	g	f,g	g	III
~~(h)~~	~~h~~	~~h~~	~~h~~	~~II~~
~~(i)~~	~~i,j~~	~~i,j~~	~~i,j~~	~~I~~
~~(j)~~	~~i,j~~	~~g,h,i,j~~	~~i,j~~	~~I~~
~~(k)~~	~~k~~	~~k~~	~~k~~	~~II~~

Iteration 4- Level III crossed out and Level IV (white)

Sos	Reachability Set	Antecedent Set	Intersection	Level
~~(a)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
~~(b)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
~~(c)~~	~~a,b,c,e,k~~	~~a,b,c,d,e,f,k~~	~~a,b,c,e,k~~	~~I~~
~~(d)~~	~~d,f,g~~	~~d~~	~~d~~	~~II~~
~~(e)~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~a,b,c,e,k~~	~~I~~
(f)	f	f	f	IV
~~(g)~~	~~g~~	~~f,g~~	~~g~~	~~III~~
~~(h)~~	~~h~~	~~h~~	~~h~~	~~II~~
~~(i)~~	~~i,j~~	~~i,j~~	~~i,j~~	~~I~~
~~(j)~~	~~i,j~~	~~g,h,i,j~~	~~i,j~~	~~I~~
~~(k)~~	~~k~~	~~k~~	~~k~~	~~II~~

4 Findings

Two important outputs are obtained based on the ISM approach applied in the study. First is the driving and dependence power diagram shown in Fig 2. Accordingly, SOs (f), (g), (h), and (i) are in the autonomous area indicating that they have comparably less driving and dependence power and may be of secondary importance in study plan design. SO (d) is independent of other outcomes but has a great driving power and is thus in independent area, while SO (j) is in close relation with other outcomes and shows a dependent relationship despite playing relatively less vital roles in study plan design. SOs (a), (b), (c), (e), and (k) are in linkage area and they are significantly important in terms of both driving power and dependence power. These SOs have correlation with other SOs and should be paid attention in order to make the best use of their driving power in the designed study plan. Among these SOs in linkage area, SO (k) has the weakest dependence power showing that it is the least dependent SO in that area, while SO (b) has the weakest driving power in area indicating that its driving power is no more than the other SOs. The analysis also shows that

SO (c) is the most important SO that has the largest driving and dependence power among all SOs in linkage area.

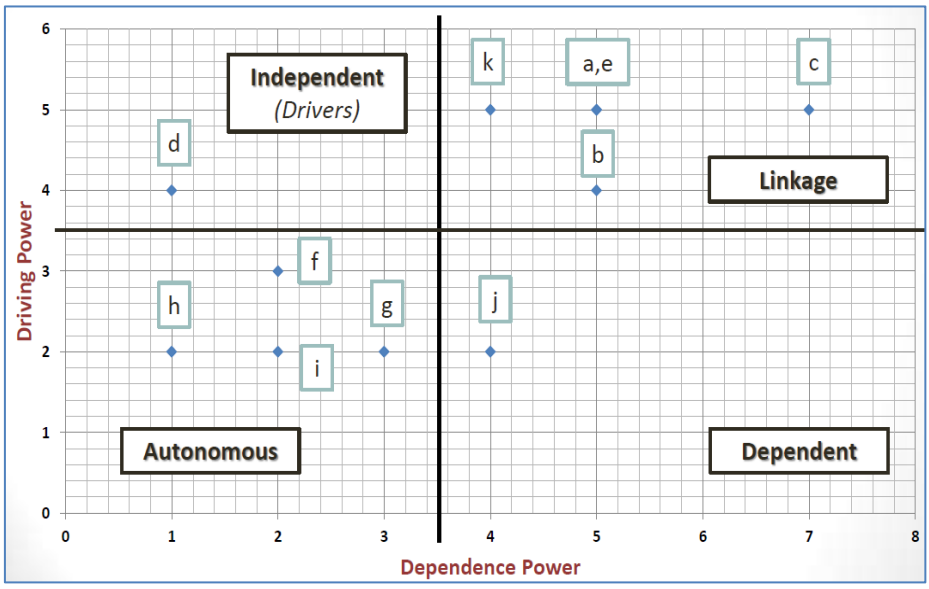

Fig. 2. Driving and Dependence Power Diagram

The second output of the ISM approach applied in the study is the proposed study plan created from prioritizing and conceptualizing all SOs. The levels at which the SOs are reflected correspond to four different levels to be considered from as it is shown in Fig 3. Accordingly, SO (f) is essential in the first level of the plan to facilitate SO (g), which will be dealt with within the context of courses taught in the second year.

In a similar manner, successes of SOs (k), (d), and (h) are affected by the achievement level of SO (g), which also affects SO (j) that located in the last level. SOs (k), (d), and (h) are linked to SOs in the fourth level of the study plan. In addition, it is shown in Fig 3 that the SOs (e),(a),(b), and (c) in the fourth level have a stronger relationships among each other which indicates that it is important to consider these SOs together in same or very close level. The unconnected SOs gives an indication of a weak or absence of relationships among them.

It is indicated that there is a lack of published articles that linked the plan of study with the ABET SOs using a scientific methodology such as ISM. However, similar study was conducted for the plan of study of the Industrial Engineering Department at King Abdulaziz University (KAU) in Jeddah, Saudi Arabia. The KAU ISM study concluded that ISM approach facilitates a clear understanding of the relationships between SOs. In addition, it indicated that "students should be trained to work in teams at the early stages of their career though the study plan, especially in the first year."[18]. Comparing both findings can provide evidences for accredited schools to prioritize the SOs and study the link among them.

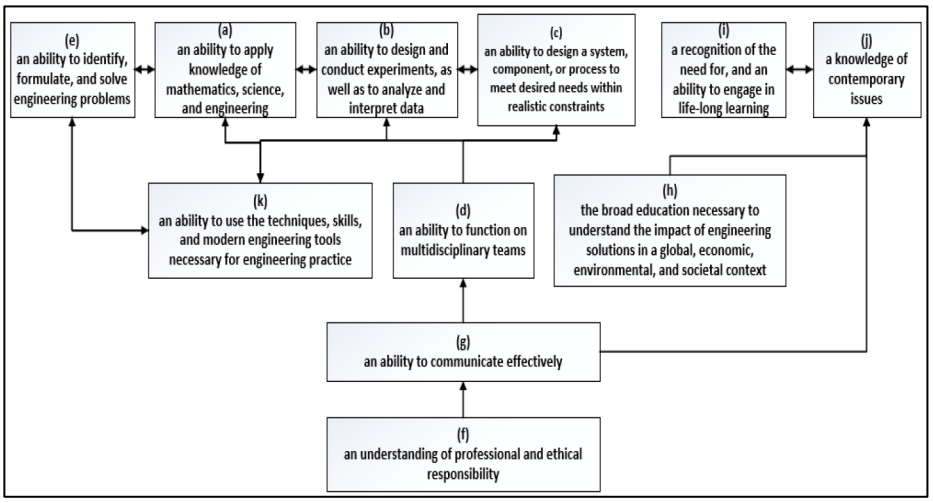

Fig. 3. Proposed Study Plan Using ISM

For instance, as we can infer from Fig 3, even if the SOs are proposed on a leveled basis and there seem to be 4 levels, it should be noted that they are not allocated to learning years, and further analysis is needed to classify them into years of education. It may be possible to start with planning of SOs starting from second year or even third year, while finishing all of the SOs within third year may also be feasible depending on the further analysis on the education system and also the SOs. This can be considered as a limitation of the study and one of the main differences between KAU ISM study and other education plans contented by the universities.

Another difference is that we provide another perspective by incorporating the data from both the Kuwait University's faculty members and key personnel from Kuwait's business companies to determine and model the relationship between Student Outcomes (SOs), and even though our sample size is not large, we are able to combine two different classes of stakeholders to design a common sense SO cluster, which is industrially different from the KAU ISM study, and which is tailored for a broader range of education periods. This in turn allows for the development of more specific programs that can include industry-based SOs in lateral phases of education program. For instance, an ability create bridges between different engineering methodologies such as operations research and C# coding or a more general approach may be incorporated into SOs as a result of key sectors' requirements.

5 Conclusion and Further Discussion

Education is of utmost importance for any country. Country policies and strategic management efforts of both governmental and private organizations heavily depend on excellence in each and every sector, and engineering as of today continues to play one of the most vital roles in terms of education.

In this study, industrial engineering program in Kuwait University is examined with regard to ABET SOs and their relationships as well as significance for the sake of program success using ISM approach. Even though SOs (f) and (g) seem less important as they are in the autonomous area, they are vital to achieve success in other SOs in the further years of education. Beyond this, it is seen that SOs with high dependence and driving powers are gained in the 3rd and 4th years of the program, and they are all linked. These SOs are, therefore, considered as objectives within the courses offered in the last two years, while communication aspects and awareness of professional and ethical responsibility are the fundamentals before starting with the technical content, and should be justified at the first two years, in order to achieve success in other desired outcomes of the program.

There are several limitations in our study which may as well be eliminated and improved in further studies. Even though our sample size contains key persons from both academic and business sectors, it is not necessarily large. There are many faculty members also many other important business companies in Kuwait, which may be included in other studies to account for a greater portion of opinions. Another aspect is related to generalization of the achieved results due to factors related to Kuwait's culture, policy and people, which significantly limit results generalization for Arabian Gulf countries or other parts of the World. It should be, therefore, kept in mind to combine ISM approach with an exact or approximate mathematical model and to increase the objectivity level and provide common-sense solution derived from multiple business sectors across multiple countries.

6 References

[1] L. Richards, S. Larry, C. Atman, K. Smith, Z. Jm, and B. Eschenbach, "The future of engineering education." 2002.
[2] "History | ABET." 2018.
[3] "2017–2018 Directory of CHEA-Recognized Organizations CHEA." 2018.
[4] "Global Presence, | ABET." 2018.
[5] "Criteria for Accrediting Engineering Programs, 2016 – 2017 | ABET." 2018.
[6] "Accreditation Policy and Procedure Manual (APPM) 2017 | ABET," 2018. .
[7] "Find an ABET-Accredited Program | ABET." 2018.
[8] K. University, "Kuwait University."
[9] A. J. Dutson, R. H. Todd, S. P. Magleby, and C. D. Sorensen, "A Review of Literature on Teaching Engineering Design Through Project- Oriented Capstone Courses," J. Eng. Educ., vol. 86, no. 1, pp. 17–28, 1997. https://doi.org/10.1002/j.2168-9830.1997.tb00260.x
[10] L. Nicolai, "Viewpoint: An Industry View of Engineering Design Education," Int. J. Engng Ed, vol. 14, no. 1, pp. 7–13, 1998.
[11] K. Behdinan, R. Pop Iliev, and J. Foster, "WHAT CONSTITUTES A MULTIDISCIPLINARY CAPSTONE DESIGN COURSE? BEST PRACTICES, SUCCESSES AND CHALLENGES," Proc. 2014 Can. Eng. Educ. Assoc. Conf., vol. 125, pp. 1–5, 2014. https://doi.org/10.24908/pceea.v0i0.5940
[12] R. Felder and R. Brent, "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria," J. Eng. Educ., vol. 92, no. 1, pp. 7–25, 2003. https://doi.org/10.1002/j.2168-9830.2003.tb00734.x

[13] L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The ABET 'Professional Skills' - Can They Be Taught? Can They Be Assessed?" J. Eng. Educ., vol. 94, no. 1, pp. 41–55, Jan. 2005. https://doi.org/10.1002/j.2168-9830.2005.tb00828.x
[14] O. Oviedo-Trespalacios, L. P. Angarita, M. Maestre-Meyer, and C. B. Correa, "Building the life-long learning competence in undergraduate engineering students with a laboratory practice in learning curve," Procedia - Soc. Behav. Sci. 2014, vol. 174, no. 2015, pp. 2021–2026, 2014. https://doi.org/10.1016/j.sbspro.2015.01.870
[15] H. J. Passow, "Which ABET Competencies Do Engineering Graduates Find Most Important in their Work?" J. Eng. Educ., vol. 101, no. 1, pp. 95–118, 2012. https://doi.org/10.1002/j.2168-9830.2012.tb00043.x
[16] R. Mathey, A. S. Reddy, and M. Shanthi, "Collaboration between Industry and Engineering Education," J. Eng. Educ. Transform., no. Special Issue: Jan. 2015, pp. 126–132, 2015.
[17] S. Levonisova et al., "Identifying Factors That Enhance Undergraduate Engineering Students' Global Preparedness," 122nd ASEE Annu. Conf. Expo., no. Paper ID: 12356, pp. 1–18, 2015.
[18] H. Alidrisi, "Development of a Study Plan for Industrial Engineering Program Using Interpretive Structural Modeling Technique," Int. J. Eng., 2015.
[19] D. W. Malone, "An Introduction to the Application of interpretive Structural Modeling," Proc. IEEE, vol. 63, no. 3, pp. 397–404, 1975.
[20] D. M. Lee, "Interpretive Structural Modeling (ISM)," 1988.
[21] R. Attri, N. Dev, and V. Sharma, "Interpretive Structural Modelling (ISM) approach: An Overview," Res. J. Manag. Sci., vol. 2, no. 2, pp. 3–8, 2013.
[22] A. Jayant, M. Azhar, and P. Singh, "Interpretive Structural Modeling (ISM) Approach: A State of the Art Literature Review," IJRMET, vol. 5, no. 1, pp. 15–21, 2015.
[23] K. Mathiyazhagan, K. Govindan, A. NoorulHaq, and Y. Geng, "An ISM approach for the barrier analysis in implementing green supply chain management," J. Clean. Prod., vol. 47, pp. 283–297, May 2013. https://doi.org/10.1016/j.jclepro.2012.10.042
[24] M. Alawamleh and K. Popplewell, "Interpretive structural modelling of risk sources in a virtual organisation," Int. J. Prod. Res., vol. 49, no. 20, pp. 6041–6063, 2011. https://doi.org/10.1080/00207543.2010.519735
[25] P. Jia, A. Diabat, and K. Mathiyazhagan, "Analyzing the SSCM practices in the mining and mineral industry by ISM approach," Resour. Policy, vol. 46, pp. 76–85, Dec. 2015. https://doi.org/10.1016/j.resourpol.2014.04.004
[26] P. S. Gour Ram Janm; Sohani, Nagendra, "Interpretive Structural Modeling of Information Sharing Barriers in Indian Manufacturing Firms," J. Supply Chain Manag. Syst., vol. 2, pp. 26–32, 2013.
[27] N. Sohani and N. Sohani, "Developing Interpretive Structural Model for Quality Framework in Higher Education : Indian Context," J. Eng. Sci. Manag. Educ., vol. 5, no. II, pp. 495–501, 2012.

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Gruendungsgarage – A Best-Practice Example of an Academic Start-up Accelerator

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Abstract—Over the past four decades, entrepreneurship has grown within universities faster than virtually any other area of intellectual pursuit. And it appears that the pace is accelerating with more universities seeking to develop programs and centers focused on entrepreneurship. Yet, understanding how to build entrepreneurship programs that empower and transform has remained challenging for some institutions. This paper investigated the development of an entrepreneurship program called Gruendungsgarage [1]. The Gruendungsgarage is a cooperation between the University of Graz (KFU) and the Graz University of Technology (TUG). Originally it was designed as an interdisciplinary and inter-university teaching format offered as an elective course where students were able to work on their own real business ideas while getting assistance from university experts as well as from successful practitioners with a wide range of experience. Because of its popularity and constant improvement, Gruendungsgarage became more and more professional and over time changed its format into an academic start-up accelerator. Setting up university start-up accelerator programs has been a worldwide proven model that enables students to intensively develop their business idea into a marketable product or service in just a few months. Since the winter semester 2017/18 Gruendungsgarage has admitted not only students but also scientific staff. University and postdoctoral researchers benefit from a wide range of Gruendungsgarage services, as technical scientists with high-tech innovation get supported by experts and entrepreneurs, creating a business model suitable to their scientific discoveries.

Keywords—Entrepreneurship Lecture, Best Practice, Academic Start-Up Accelerator

1 Introduction

According to the changes in the economy and workforce, entrepreneurship and corresponding education are subjects of current interest throughout Europe. Lepuschitz et al. (2018) determine that these changes call for an entrepreneurial mindset. They argue that through an appropriate education at school and university levels, students can acquire relevant skills and mindset required for entrepreneurship [2]. Several research articles focus on the creation of entrepreneurship programs offered at universities. It is, therefore, valuable to perform a qualitative perspective on the educational practices of

an entrepreneurial program called Gruendungsgarage [3]. Due to a five years' experience, the teaching program serves as a best practice approach to entrepreneurship education within tertiary education. The paper provides an overview of procedures, findings and approaches in structuring entrepreneurship education within the program. Originally, the Gruendungsgarage started as an interdisciplinary teaching format offered as an elective course in order to provide support for preparing innovative and knowledge-based start-up projects developed by students of the University of Graz (KFU). A volume extends over one university semester and is divided into several teaching and workshop phases. After two successful volumes, the University of Graz (KFU) enter into a partnership with the University of Technology (TUG) with the aim to attract the attention of students with a technical background and an inclination to start a business. On the one hand this partnership increased the educational diversity among the participants. On the other hand, the number of technology-oriented start-up projects hosted by the Gruendungsgarage also increased due to this cooperation. The focus of the program is on practical activities which reflects the entrepreneurship reality in a controlled environment. Practical tasks are mainly used to teach entrepreneurship, rather than a reliance on traditional classroom teaching. Program leaders originate from both academia and industry, with the aim of blending theoretical and practical knowledge [4]. The proportion of theory-based knowledge transfer is deliberately kept small and the teaching sessions are always outside a typical lecture room to enable a creative work climate. As a result, the participants can experiment with their business ideas get them ready for market and prepared for founding a start-up company. Another characteristic is the group-based learning method, which allows the teams to get an idea about how it is to work with a new venture team [5]. The teambuilding process is a very important experience for each individual to become aware of their role inside the team to define the areas of responsibility of each founder.

The aim of this paper is to introduce the proven concept of the Gruendungsgarage and to examine the support services participants receive during the accelerator program. Furthermore, we are interested in understanding the success factors of start-up initiatives in higher education to deliver training that meets the stakeholder needs.

1.1 Expanding target audience to increase the scope

Benefiting from the strategic project "entrepreneurial university" which was launched at the TUG in 2015, the Gruendungsgarage moves into the spotlight of the entrepreneurial education and paves the way for academic start-ups. The aim of this new strategic orientation was to stimulate the entrepreneurial spirit of the students but also employees and develop third mission policies within the TUG. [6] As a result, the Gruendungsgarage expanded its target audience – this means that services are not for students exclusively. Since the winter semester 2017/18, scientific staff is also eligible to apply proposing their business ideas as well as benefiting from the same kind of support and network use.

The opportunity for scientific staff to participate in the Gruendungsgarage was internally promoted to draw the attention of the new target group towards new entrepreneur-

ial service offers. Furthermore, the Gruendungsgarage gets integrated into the postgraduate training catalogue of the TUG to make it more visible for the scientific staff. After attending the program, they get an official confirmation that is also credited to them as a further education.

According to a recent study of the IfM Bonn, many good ideas arise at universities but the implementation is rarely tackled. [7] For this reason a recently launched national funding program called "Spin-off Fellowship" should support scientists to commercialize their intellectual property. Over a period of 18 months, the scientists are released from their work duties in order to develop their research results, create a business plan and prepare their business formation after finishing the funding program. As an integrated component of the strategic project "entrepreneurial university" at the TUG, the Gruendungsgarage assembled a comprehensive training catalogue to provide the fellows with a broad range of business and legal knowledge to teach them entrepreneurial skills.

1.2 Success factors of the gruendungsgarage

The ongoing success of this format is based on special characteristics that make the Gruendungsgarage an academic start-up accelerator and hence more than just a lecture. One of the features represents the opportunity for students and scientific staff to work on their own business idea which increases their motivation and willingness to participate. After their successful participation, all members get the Gruendungsgarage certificate, and students also benefit from it by receiving 2 ECTS credits. The latter is more a symbolic reward in consideration of the effort they provide during the semester.

Beyond that, Gruendungsgarage offers entrepreneurs the support of university lectors with an expertise in Entrepreneurship as well as an extensive network of experienced business professionals. The collaboration with people interested in mentoring is an essential part of the program to improve the long-term functioning of start-ups and help them to develop their network. There is a strong interest by business professionals to become mentors why new business professionals apply for the work as a mentor on a regular basis. The organizers of the Gruendungsgarage strive to find every team two complementary mentors that suit their situation, needs and development stage. The mentors' background, know-how and interests is taken into account to ensure maximum compatibility. Business professionals play a significant role as they guide the teams during the whole semester and provide feedback at an early stage where they haven't already started a business. In that way, the teams may easily rearrange or modify their business ideas without losing their precious time.

Due to the increasing awareness, Gruendungsgarage can rely on 26 active mentors who cover almost every field of starting a business. Their consulting services range from business modelling, design-thinking, inbound logistics and online marketing, intellectual property right, and software development to legal and tax advice.

Once a semester, the Gruendungsgarage organizes so-called "mentoring days" where the teams get the chance of a consultation appointment to seek the advice of all mentors and not only from those who are assigned to them. This special event is an organizational improvement. Due to an evaluation of the teaching program by the participants

as well as a survey of the mentors has shown that it is particularly difficult for teams and mentors to arrange a suitable date for everyone. The "mentoring days" enable a more efficient time management and lead to a more intensive exchange between the two parties. In order to get as many mentors as possible for several hours at a time, a doodle survey was performed. After the dates were determined with the mentors, the teams are provided with a great opportunity to book a time slot with each mentor, allowing participants to receive a comprehensive consultation from different experts in only one session.

A further improvement of the teaching format is the stronger integration of alumni in the knowledge transfer and the exchange of experience with beginners of the Gruendungsgarage. Every semester, one workshop is led by alumni who successfully started a business after their time at the Gruendungsgarage. These alumni briefly present an outline of their career and share their experience with the teams of the current volume. But they do not only talk about aspects of their success – they also share their failures and lessons and what they have learnt from them. This is a great opportunity for the newcomers to see what it takes to become an entrepreneur and which challenges are waiting for them after finishing the program.

An additional initiative was established to enhance the commitment of the alumni and the mentors of the Gruendungsgarage in the summer semester 2018. The so called "alumni academy" is a regular event where alumni and mentors can exchange views on current topics and issues of the startup scene. The goal is to learn from each other, to exchange ideas and to maintain the common network. The "alumni academy" offers space for discussions about challenges related to entrepreneurial growth and which aspects of international expansion are especially important for startups and young companies. The input is provided by alumni of the Gruendungsgarage network which are confronted with these challenges and report from their experience.

Further assistance is offered in the fields of financing and funding. All of the teams which are currently hosted by the Gruendungsgarage are in the (pre-) seed phase where public funding represents a significant source of income. Therefore, the teams get advice which funding institutions are the most promising to address in the early stage and what they need to consider at the submission of the funding application.

Besides the mentors and the alumni, the network of the Gruendungsgarage also includes investors and business angels. It offers to the promising teams start-up funding to facilitate the realization of their own business ideas. Although the teams get support through the regional and national funding agencies in Austria, private investors are essential at a certain point, as it makes them important partners of the Gruendungsgarage.

2 Structure of the Gruendungsgarage

Every university semester, students and scientific staff wishing to start-up a business can apply for the program by sending an online application to the executive board of the Gruendungsgarage. In a semi-structured online form, the applicants shortly describe their initial situation, the business idea, the current status and the next steps they are planning in regard to their project. The submission deadline ends about two weeks after

the official semester start. Subsequently, a team of experts evaluates all the business ideas in terms of the level of innovation as well as the potential and accessible scalability of the idea. As a part of the evaluation, attention on the maturity level of the business ideas are given as well to ensure not having projects at the Gruendungsgarage who are already on the brink of market entry because the aim of the accelerator program is to support idea projects which are situated in the (pre-) seed phase. In this early stage, university experts and external mentors provide valuable input through a balanced mixture of strategic knowhow and practical experience.

The Gruendungsgarage offers students and scientific staff an extensive support why a maximum of ten teams can participate at the accelerator program per semester. Throughout the program, the teams receive a wide range of start-up support. This includes class-room-lessons, workshops, consulting sessions, exercises, discussions with the group, and also with alumni teams of the Gruendungsgarage who have already founded a business. The entire course of events is illustrated in Figure 1 and can be described as follows [8].

After the submission deadline all applications from students and scientific staff are collected and evaluated. Those who do not meet the requirements are sorted out by a team of experts who finally determine the ten best business ideas and link them to those mentors whose field of expertise best matches the idea.

Shortly after the decision, the selected teams get informed about their qualification and get invited to a kick-of event. This event marks the official start of the accelerator program where the teams present their business ideas to the whole group in order to get feedback. Furthermore, it helps the teams to get to know each other and to start networking. During the kick-off event, the teams also get in touch with their assigned mentors for the first time to set their target agreements.

As Figure 1 shows, after the kick-off event several phases begin. The first two weeks are characterized by a start-up phase where the teams mainly work on their business models. Generally, the teams enter the Gruendungsgarage with a rough business idea only and usually do not deal with a business model. In the second phase, the teams receive some workshops which deal with start-up relevant topics like business model development, design-thinking, online- and growth marketing, intellectual property rights and legal and tax advice.

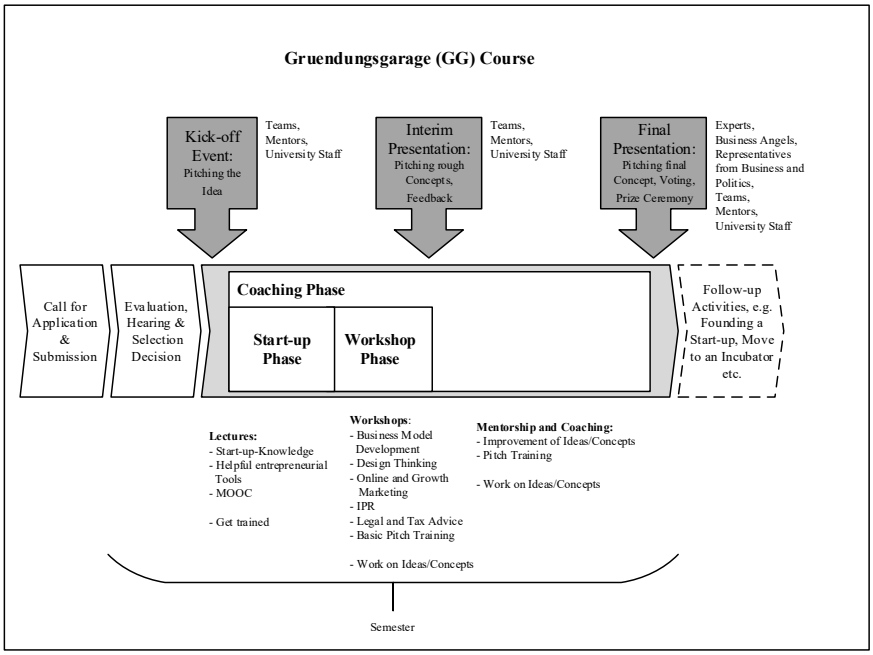

Fig. 1. Structure of the Gruendungsgarage

Over the numerous volumes, this workshop phase has changed in terms of period and frequency in which the workshops are offered. The program leaders of the Gruendungsgarage realized the need for workshop-days instead of several workshop-units, which usually used to take two hours. The disadvantage of the previously offered workshop-units is that just when the teams reach a productive working phase, they have to stop because of the short lessons. It turned out that the teams are much more productive if they complete full workshop-days where they get time to focus on certain tasks and acquire the skills to start a business.

Another improvement of the workshops was the use of massive open online courses (MOOCs) which are combined with the business model workshop. A couple of days before the workshop starts, the participants need to watch online videos about creating a business model.

These videos were specially made to support the teams and make it easier for them to work with a business model canvas on the first workshop day. The past showed that participants who have never worked with a business model canvas before had frequently difficulties to follow the instructions and so they often ran out of time. It turned out, that MOOCs were the right approach to raise the output of the workshop which leads to an enrichment of the knowledge transfer [9].

After about six weeks, there is an interim presentation where the teams present the progress and their results to the whole group. Again, every team receives feedback concerning the pitch, important developmental steps and their level of target achievement.

The third phase is called "coaching phase" and extends over the whole semester. It is characterized through discussions with the mentors, experts and alumni of the Gruendungsgarage. The aim of this coaching sessions is the development of the business models of the teams to get them ready for market. Beside the workshop-phase, the procedure of the coaching-phase has also changed over time. In former volumes, the participants were advised to make individual appointments with mentors from businesses and university to get feedback on their elaborated results. However, the experience has shown that it is difficult to find common dates where both, the team members and the mentors, would have time. Because of this reason, the so-called "mentoring-days" were introduced to offer the teams one to two days where the majority of the mentors are available for several hours. Especially for the busy mentors, this organizational change represents an enormous relief.

The Gruendungsgarage concludes with a final presentation at the end of the semester where the teams get the opportunity to present their business ideas to an audience consisting of investors, business angels and people from the local start-up scene. The audience votes for the top three teams who receive great prizes from sponsors and partners of the Gruendungsgarage [8].

3 Facts and Figures

As seen in Figure 2, a total of 205 students and scientific staff took part at the Gruendungsgarage during the last five years which led to a support of 101 projects/teams during this time. 33 out of these 101 teams actually started a business after attending the academic start-up accelerator and 28 of them are still operating on the market. A study was conducted to ask for the number of jobs being created by these start-ups. It turned out that more than 130 jobs were created which is a valuable contribution to the domestic economy.

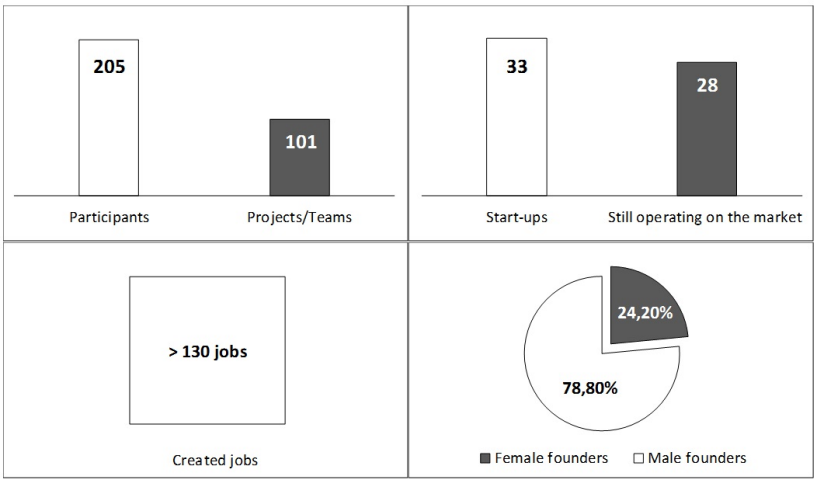

Fig. 2. Key figures of the Gruendungsgarage Vol. 1-11, retrieved December 2018

The percentage of women among the 28 active start-ups of the Gruendungsgarage is 24.20% which is well above the Austrian and the European average. According to a study by the European Startup Monitor (ESM), the percentage of female start-up founders in Austria is only 7,1% and in Europe it is 14,8% on average [10]. Thus, the Gruendungsgarage represents a true diversity format through its percentage of female start-up founders.

In the last four volumes (volume 8-11), the data collection was systematized to allow a more detailed analysis of key figures such as:

- University affiliation of the teams
- Team composition
- Educational background of the participants

A notable aspect of the data analysis was the number of applied and selected teams of the Graz University of Technology. While initially, most of the applicants were students or members of the KFU, the number of applied and selected teams from the TUG has increased during the last four volumes. More and more teams with a technical background are interested in participating in the accelerator program to benefit from an authentic entrepreneurship experience, as it exposes academic participants to real world start-up problems and opportunities.

Figure 3 compares the number of teams that applied for the Gruendungsgarage and those that have been selected, labeled by their university affiliation.

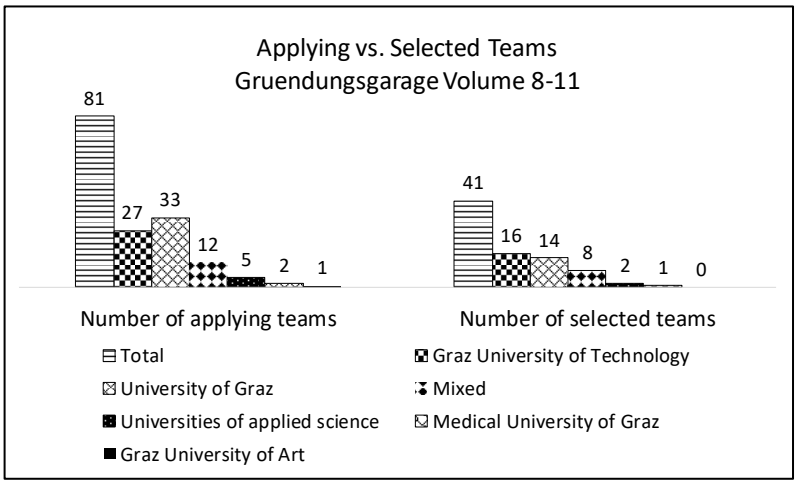

Fig. 3. Applying vs. Selected Teams at the Gruendungsgarage Vol. 8-11

Although the number of participants from universities with a technical focus is increasing, there is still a lack of heterogeneous teams. Over the last four volumes there were only eight mixed teams out of 41 with a different field of study/discipline.

Furthermore, there is a trend towards digitalization in terms of the products, processes, and business models of the selected teams and those who are currently in the

start-up process. For the development of digital business models, programming skills are an advantage that qualifies students and scientists of the TUG and universities of applied science to participate at the Gruendungsgarage [11].

To extend the investigation, the e-mail correspondence between the program leaders and the teams of the Gruendungsgarage were analyzed to get an idea of the content exchanged via this medium. It turned out that there is little exchange regarding subject-specific issues. Instead, mainly organizational topics are discussed via e-mail. Frequently, teams contact program leaders of the TUG with technical questions, with the intent to get access to specific institutes at Graz University of Technology that can offer them technical support for their products. However, strategic questions concerning the business models are typically discussed in person during one of the numerous workshops, meetings, or events of the Gruendungsgarage.

4 Discussion and Outlook

After ten volumes and more than 25 successfully realized projects, the Gruendungsgarage has demonstrated its valuable contribution for students and scientific staff interested in starting their own business. Due to the increasing interest of participants with a technical background, the range of support services needs a constantly review to meet the needs of the different stakeholders. Therefore, the service offerings of the Gruendungsgarage gets constantly evaluated and improved in order to meet the needs of a broader and heterogeneous group of students and scientific staff [12].

Nevertheless, the latter group is still underrepresented at the Gruendungsgarage and needs more attention to show them the possibilities and advantages of an entrepreneurial career. It has shown that generally PhD-students or postdoctoral researchers with a fixed-term employment contract had participated the program during the last few volumes while scientific staff with a contract of employment of indefinite duration showed practically no intention in becoming an entrepreneur. An investigation of the factors which are beneficial or obstructing for university scientist to attend an entrepreneurial program and thus effectively start a business would be helpful to effectively promote an entrepreneurial program to this group. In any case, it is essential to create an entrepreneurial awareness throughout the entire university to foster individuals who have the motivation and capacity to identify an opportunity and pursue it in order to produce new value and economic success.

A further possibility for optimizing the Gruendungsgarage refers to the diversity within the teams. Diverse people are sorely underrepresented in the business world – particularly in start-ups – and the Gruendungsgarage is no exception. Until now, many teams consisted of students or scientists from the same university or the same discipline, which limited their mindset and reduced their creativity [13]. To remedy such unsatisfactory tendencies, the program leaders thought about a change in the application process. For instance, the teambuilding process could take place at the beginning and not before the Gruendungsgarage starts. In a kind of matchmaking, potential founders with different fields of expertise would get to know each other and exchange ideas about possible partnerships before they start the regular program. A second modification of

the teaching format aims to adopt an approach where universities exploit their intellectual property generated through theoretical and applied research. According to this approach, the Gruendungsgarage could offer students and scientific staff access to the patent archive where they analyze all the patents, pick an idea, and consider how they can commercialize it. This setup could lead to a format where participants of the Gruendungsgarage are no longer forced to apply with a business idea but still prove their entrepreneurial skills.

Five years of experience have shown that the teaching format as the Gruendungsgarage is essential for the local start-up scene in order to get a comprehensive support at a very early start-up phase. The numerous applications verify the interest of particularly students and scientific staff in the topic entrepreneurship which can be used as an evidence that there is a remarkable demand for more practical entrepreneurship education.

5 References

[1] S. Hoskinson and D. F. Kuratko, "Innovative Pathways for University Entrepreneurship in the 21st Century," *Advances in the study of entrepreneurship, innovation & economic growth*, vol. 24, p.1, 2014. https://doi.org/10.1108/s1048-473620140000024016

[2] W. Lepuschitz,G. Koppensteiner, U. Leeb-Bracher, K. Hollnsteiner, and M. Merdan, "Educational Practices for Improvement of Entrepreneurial Skills at Secondary School Level," *International Journal of Engineering Pedagogy*, vol. 8, no 8, pp. 111-112, 2018. https://doi.org/10.3991/ijep.v8i2.8141

[3] N. Antal, B. Kingma, D. Moore, and D. Streeter, "University-wide Entrepreneurship Education," in I*nnovative Pathways for University Entrepreneurship in the 21st Century*, vol 24, *Advances in the Study of Entrepreneurship, Innovation and Economic Growth*, vol 24, JAI Press, pp. 227-254, 2014. https://doi.org/10.1108/s1048-473620140000024009

[4] C. Nieuwenhuizen, D. Groenewald, J. Davids, L.J. Rensburg, and C. Schachtebeck, „Best practice in entrepreneurship education," *Journal of Problems and Perspectives in Management*, vol 14, no 3, pp. 528-536, 2016. https://doi.org/10.21511/ppm.14(3-2).2016.09

[5] R. Harms, "Self-regulated learning, team learning and project performance in entrepreneurship education: Learning in a lean startup environment," *Journal of Technological Forecasting & Social Change*, vol. 100, pp. 21-28, 2015. https://doi.org/10.1016/j.techfore.2015.02.007

[6] Online Pressestelle der Technischen Universität Graz, „Ein starkes Team für die TU Graz Das Rektorat 2015 – 2019 - Die unternehmerische Universität als zusätzlicher strategischer Schwerpunkt zu Internationalisierung, Kooperation und Profilbildung," September 2015. [Online]. Available: https://pressearchiv.tugraz.at/pressemitteilungen/2015/29.09.2015.htm [Accessed Nov. 7, 2018]. https://doi.org/10.1007/s00735-015-0580-9

[7] T. Bijedić, S. Chlosta, S. Hossinger, A. Kasdorf, S. Schneck, C. Schröder, and A. Werner, in collaboration with S. Nielen, and S. Oschmann, "Gründungserfolg von Wissenschaftlern an deutschen Hochschulen, IfM Bonn," *IfM-Materialien no. 257*, July, 2017.

[8] S. Vorbach, "Lecturing Entrepreneurship at Graz University of Technology – The Case of Gruendungsgarage," presented at 20th International conference on Interactive Collaborative Learning, Budapest, Hungary, 2017.

[9] G. Mayende, A. Prinz, G. Maurice, N. Isabwe, and P.B. Muyinda, "Learning Groups in MOOCs: Lessons for Online Learning in Higher Education," *International Journal of Engineering Pedagogy*, vol. 7, no. 2, p. 5, 2017. https://doi.org/10.3991/ijep.v7i2.6925

[10] T. Kollmann, C. Stöckmann, S. Hensellek, and J. Kensbock, "European Startup Monitor," *europeanstartupmonitor.com*, 2016. [Online]. Available: https://europeanstartupmonitor.com/fileadmin/esm_2016/report/ESM_2016_PPT_EN.pdf. [Accessed Nov. 8, 2018].

[11] E. Poandl, M. Glinik, and R. Taferner, "Digitalisierung in Academic Startups – Trends bei Gründungsprojekten der Gründungsgarage Graz," presented at 22nd Annual Interdisciplinary Conference on Entrepreneurship, Innovation and SMEs, Stuttgart, Germany.

[12] P. Holzmann, E. Hartlieb, and M. Roth, "From Engineer to Entrepreneur - Entrepreneurship Education for Engineering Students: The Case of the Entrepreneurial Campus Villach," *International Journal of Engineering Pedagogy*, vol. 8, no. 3, p. 30, 2018. https://doi.org/10.3991/ijep.v8i3.7942

[13] R. Novellus, "Why Diversity Is Needed In Startups," June 2016. [Online]. Available: https://www.forbes.com/sites/yec/2017/06/15/why-diversity-is-needed-in-startups/#6fcbf08476ea [Accessed Nov. 15, 2018].

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Development of Integrated Curricula for the Master of Engineering Programs Using the CDIO Framework

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Abstract—This research presents the revision of the current curriculum of the Master of Engineering program at Camarines Sur Polytechnic Colleges in the Philippines through series of consultations and focus group discussions with the faculty and students of the graduate program and industry practitioners, and the development of integrated curricula using the CDIO framework. Standards 1, 2, 3, 4 and 5 and syllabus v2.0 of the CDIO framework were used in the development of the integrated curricula. Graduate attributes were developed, and the result of the industry needs survey served as one of the bases in the integration of various skill sets in the integrated curricula for the master of engineering programs.

Keywords—CDIO, CDIO framework, CDIO standards, CDIO syllabus, curriculum, integrated curriculum, Master of Engineering

1 Introduction

The outcomes of the student learning can be determined by how well an educational institution design and to implement the entire curriculum for a specific program. The development of curriculum for educational programs can be influenced by a number of sources. The goals of the program could be defined based on the funding source, the community, government departments of education (state and federal level), or by the educator who is designing the activity [1].

CDIO is an international initiative in reforming education. CDIO framework has been the current trend, and it influences the reformation of engineering education. It is an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamental set in the context of Conceiving-Designing Designing – Implementing – Operating (CDIO) real-world systems and products [2]. The current educational setup must be aligned to the current needs of the industry and skills gap is a common problem between university products and industry needs [3]. To cope in this competitive world, a well-designed curriculum must be designed to satisfy with the international standards of engineering education that focus on the attainment of the needs of the industry.

In the Philippines, CDIO was first to introduced with the partnership of Singapore Polytechnic and Temasek Foundation. One of the nine State Universities and Colleges

in the Philippines is the Camarines Sur Polytechnic Colleges that undergone series of trainings and seminars both in the Philippines and Singapore on the CDIO Framework. Six faculty members of the College of Engineering were trained to become Master Trainers that has the role of cascading CDIO not just in the college but to all Colleges and Universities in the Philippines.

Camarines Sur Polytechnic Colleges popularly known as CSPC is a state college in the Philippines. It is mandated primarily to provide higher technological, professional and vocational instruction and training in fisheries, trade and technology, arts and sciences, as well as short term technical and vocational courses, as the Board of Trustees may deem necessary, and shall promote researches in the exploration and conservation of natural resources in the province [4]. The vision of the college is to be the regional center of excellence in polytechnic education. Presently, CSPC has two campuses: the main campus in Nabua, Camarines Sur and Buhi Extension campus. In the main campus, the institution has 5 colleges, namely, College of Engineering, College of Health Care Technology, College of Management and Entrepreneurship, College of Information and Communications Technology, and College of Education, Arts and Sciences. The college offers 2 levels of educational programs in various disciplines: bachelor's degree and master's degree programs.

CSPC has been one of the leading engineering institutions in the Bicol Region. The College of Engineering puts its goals in providing quality instruction and training in engineering through the ladderized curricula in civil, electrical, mechanical and electronics engineering which are responsive and relevant to the needs and development of the service area in particular and the country in general as well as develop total quality engineers and technology researchers for industry and society to maximally contribute to sustainable national development [5].

The first master's program offered by the college in the last 20 years was the Master of Arts in Teaching Engineering Technology (MATET) and then it was changed to Master of Arts in Engineering Technology (MAET) and Master in Engineering Technology (MET). Currently, the name of the program was change in 2014 to Master of Engineering (M.Eng'g). The program offers specializations in Civil Engineering, Mechanical Engineering, Electrical Engineering and Electronics Engineering. Based on the tracer study of Barandon conducted in 2016, the graduates of the program at CSPC from 2004 to 2015 is fifty-five (55). From 2016 to present, the enrollees of the program greatly increased and in 2018, the current number of students is eighty (80).

CSPC is one of the two higher education institutions in Bicol region to offer a master's program in engineering catering engineering professionals and practitioners in the six (6) provinces of Bicol. The main objective of the study is to develop integrated curricula for the master of engineering programs using the CDIO framework guided by the current educational standards and requirements of the graduate program in engineering, and the results of industry needs survey.

2 Literature Review

The following are reviews on CDIO that served as the basis in the development of the integrated curricula for the master of engineering programs.

2.1 CDIO and the Educational Standards and Accreditation

The adoption of the CDIO Initiative at the School of Engineering, Nanyang Polytechnic, Singapore contributed to the ABET accreditation of the Diploma in Aerospace and Aeronautical Engineering. The CDIO played a key role in meeting the ABET criteria; the success of the accreditation within a short span of time is shaped by the strategic foundation for NY organizational excellence – Culture, Concept, Capability and Connection/Collaboration [6].

CDIO standards are accepted to be compliant with the Washington accord. With the CDIO process, the CDIO Standards and the CDIO Syllabus, many scholarly contributions have been made around cultural change, curriculum reform and learning environments. The CDIO Syllabus cast into the Australian context by mapping it to the Engineers Australia Graduate Attributes, the Washington Accord Graduate Attributes and the Queensland University of Technology Graduate Capabilities [7].

The Tomsk Polytechnic University carried out the analysis of the existing Academic Standard to understand whether it requires some changes and to identify the possibilities of its improvement. The analysis was aimed at the development of a basis for a new edition of the TPU Standard in the frame of CDIO context [8].

With these literatures, it is to note that CDIO is a worldwide accepted framework for engineering education. It conforms to various educational standards such as the Washington Accord and incorporates outcomes-based education. It is compliant to the standards of engineering education and accreditations of programs

2.2 CDIO standards

The CDIO framework is consists of 12 CDIO Standards [9]. Standard 1 focused on program philosophy. Standards 2, 3 and 4 is on the curriculum development. Standards 5 and 6 are on design-build experiences and workspaces. Standards 7 and 8 are on new methods of teaching and learning. Standards 9 and 10 is on faculty development. And standards 11 and 12 is on assessment and evaluation.

2.3 CDIO syllabus

The syllabus is the cornerstone of CDIO. It offers rational, complete, universal and generalizable goals for undergraduate engineering education [10]. The CDIO syllabus was developed through discussions with focus groups comprised of various stakeholders, and by reference to other documentation of the time [11]. The CDIO syllabus is composed of learning outcomes that are classified into four high-level categories, namely, technical knowledge, personal and professional attributes, interpersonal

skills, and the skills specific to the engineering profession. Table 1 shows the CDIO Syllabus v2.0 [12].

Table 1. CDIO Skill Sets

CDIO Syllabus v2.0
1. Disciplinary Knowledge and Reasoning 1.1 Knowledge of Underlying Mathematics and Science 1.2 Core Engineering Fundamental Knowledge 1.3 Advanced Engineering Fundamental Knowledge, Methods and Tools
2. Personal and Professional Skills and Attributes 2.1 Analytical Reasoning and Problem Solving 2.2 Experimentation, Investigation and Knowledge Discovery 2.3 System Thinking 2.4 Attitudes, Thought and Learning 2.5 Ethics, Equity and other Responsibilities
3. Interpersonal Skills: Teamwork and Communication 3.1 Multidisciplinary Teamwork 3.2 Communications 3.3 Communications in Foreign Languages
4. Conceiving, Designing, Implementing, and Operating Systems in the Enterprise and Societal Contexts 4.1 External, Societal and Environmental Context 4.2 Enterprise and Business Context 4.3 Conceiving, Systems Engineering and Management 4.4 Designing 4.5 Implementing 4.6 Operating

3 Methodology

This study was focused on the development of integrated curricula for the master of engineering programs using the CDIO framework. The Master of Engineering Programs at Camarines Sur Polytechnic Colleges, a higher education institution in the Philippines was the subject of the study. Revisions of the curricula were done through a series of consultations and FGDs with the faculty and students of the graduate program, and industry practitioners in order to obtain the most important courses and descriptions to be developed. Review of the CDIO standards and syllabus formed part in the whole processes of the development of the integrated curricula. Graduate attributes were developed, and industry needs survey on the expected proficiency of graduate students were gathered that served as inputs in the integration of the CDIO skill sets in the developed curricula. The questionnaire survey was obtained using the CDIO Syllabus v2.0. Respondents were asked to assess the expected level of proficiency, using a set of descriptors as shown in Table 2, in the range of skill sets of the CDIO syllabus [13].

Table 2. Expected Level of Proficiency Descriptors

1	To have experienced or been exposed to
2	To be able to participate in and contribute to
3	To be able to understand and explain
4	To be skilled in the practice or implementation
5	To be able to lead or innovate in

The participants of the study were classified into two groups. The first group is the composition of the faculty and students of the graduate program, and industry practitioners. They served as the informants to the series of consultations and FGDs in the revision of the curricula which include the course contents and descriptions. The second group of respondents is the primary engineering industries in the Bicol region, Philippines where the majority of graduate students are employed. They served as the respondents of the industry needs survey in determining the expected levels of proficiency of graduate students. Arithmetic mean and standard deviation were the statistical tools used in the analysis of data. Cronbach's Alpha was used to determine the reliability of the survey. Microsoft Excel was used in the analysis of the data.

4 Results and Discussions

4.1 Graduate Attributes

On the curriculum development process, five CDIO standards were involved. These are standards 1, 2, 3, 4 and 5 [14]. To meet standard 1, it is understood to indicate that the curriculum has adopted CDIO as a context for the master of engineering education. To meet standard 2, graduate attributes are necessary. Graduate attributes are essential factors in planning the curriculum of any university. The five themes generated represent the main areas of engineering attributes regulated by national bodies [15]. These are knowledge base, professionalism, problem solving, diverse work settings and design. These attributes were derived from the data of countries under the Washington Accord. Currently, the college doesn't have clear statements on the graduate attributes. The proposed attributes were developed and meet the global graduate attribute themes and categories as shown in Table 3.
The graduate attributes conformed to the CDIO knowledge and skill sets from CDIO syllabus as shown in Table 4.

Table 3. Proposed CSPC Graduate Attributes

No.	Global Themes	Proposed Graduate Attributes	
1	Knowledge Base	Deep Discipline Knowledge	Graduates who have the knowledge and mastery of the fundamental and advanced concepts required for effective practice of their respective fields of disciplines.
2	Professionalism Problem Solving Design	Professional Skills and Competence	Graduates who have basic and advanced practice in their fields, able to think, design, build and solve problems to respond to the needs of the industry and community.
3	Diverse Work Settings	Personal and Interpersonal Skills	Graduates apply effective communication skills both orally and in writing, give importance to life-long learning, and work effectively in multi-disciplinary and multicultural teams.
4	Diverse Work Settings	Socially Responsible and Ethical	Graduates give importance to moral values and beliefs, and understand social and ethical responsibilities.
5	Design	Productivity	Graduates contribute to nation-building and development, and industrial innovation through creative generation of technologies.

Table 4. CDIO Skillsets-Future Graduate Attributes Mapping

CDIO Skill Sets based on CDIO Syllabus v.20	Desired Graduate Attributes				
	1	*2*	*3*	*4*	*5*
1. Disciplinary Knowledge and Reasoning					
1.1 Knowledge of Underlying Mathematics and Science					
1.2 Core Engineering Fundamental Knowledge					
1.3 Advanced Eng'g. Fundamental Knowledge, Methods & Tools					
2. Personal and Professional Skills and Attributes					
2.1 Analytical Reasoning and Problem Solving					
2.2 Experimentation, Investigation and Knowledge Discovery					
2.3 System Thinking					
2.4 Attitudes, Thought and Learning					
2.5 Ethics, Equity and other Responsibilities					
3. Interpersonal Skills: Teamwork and Communication					
3.1 Multidisciplinary Teamwork					
3.2 Communications					
3.3 Communications in Foreign Languages					
4. Conceiving, Designing, Implementing, and Operating Systems in the Enterprise and Societal Contexts					
4.1 External, Societal and Environmental Context					
4.2 Enterprise and Business Context					
4.3 Conceiving, Systems Engineering and Management					
4.4 Designing					
4.5 Implementing					
4.6 Operating					

4.2 Industry Needs Survey Results

Twenty (20) questionnaires were returned. The computed Cronbach's Alpha was 0.855 which is higher than 0.700, thus, the survey was reliable. Table 5 shows the result of the survey of the proficiency expectation from the industry. It is found that multidisciplinary teamwork, advanced engineering fundamental knowledge, methods and tools, attitudes, thought and learning, ethics, equity and other responsibilities, and communications were the top expectations. The lowest expectations are communications in foreign languages and enterprise and business context. Results show similarities of the findings of Kuptasthien [16] in 2014. Also, in the results of the study of Ercan, et al., [17], they observed that engineering as well as communication and teamwork skills of students participated in their program developed significantly, which proves that these skills must be integrated in the curriculum.

Table 5. Result of Industry Needs Survey

No.	Skill Sets	Mean	Std. Dev.
3.1	Multidisciplinary Teamwork	4.500	0.671
1.3	Advanced Eng'g. Fundamental Knowledge, Methods and Tools	4.250	0.829
2.4	Attitudes, Thought and Learning	4.250	0.622
2.5	Ethics, Equity and other Responsibilities	4.200	0.600
3.2	Communications	4.200	0.600
1.2	Core Engineering Fundamental Knowledge	4.150	0.572
4.4	Designing	4.150	0.654
2.1	Analytical Reasoning and Problem Solving	4.050	0.669
2.3	System Thinking	4.050	0.497
4.3	Conceiving, Systems Engineering and Management	4.000	0.548
1.1	Knowledge of Underlying Mathematics and Science	3.950	0.589
4.5	Implementing	3.850	0.853
2.2	Experimentation, Investigation and Knowledge Discovery	3.750	0.698
4.1	External, Societal and Environmental Context	3.700	0.900
4.6	Operating	3.700	0.843
3.3	Communications in Foreign Languages	3.550	0.669
4.2	Enterprise and Business Context	3.500	0.806

4.3 Revisions of the curriculum

The revision of the curriculum was done through a series of consultations and FGDs with the faculty and students of the graduate program, and industry practitioners. The contents of the curriculum were based on the needs of the industry and the capability of the faculty members to handle specialized courses. The faculty suggested that the major courses should only focus on one specialization in each program since the previous curriculum focuses on various specializations. In this revision, four major courses were designed in each program as shown in Table 6.

Table 6. Proposed Curriculum: Master of Engineering in Civil Engineering

Foundation Courses (12 units)			
Course Code	**Pre-Requisite /Co-Requisite**	**Course Title**	**Units**
ET 200	None	Engineering Research and Development	3
ET 201	None	Probability and Statistical Concepts in Engineering Planning and Design	3
ET 202	None	Computer Engineering	3
ET 203	None	Advanced Engineering Mathematics I	3
Core Courses (15 units)			
ET 204	ET 203	Advanced Engineering Mathematics II	3
ET 205	/ET 203 /ET 202	Numerical Methods with Computer Applications	3
ET 206	None	Production Engineering and Management	3
ET 207	ET 202	Computer-Aided Design Applications	3
ET 208	None	Environment, Energy & Technology Management	3
M.Eng'g. in Civil Engineering: Structural Engineering (12 units)			
CE 200	ET 204, ET 205	Advanced Structural Analysis	3
CE 201	ET 204, ET 205	Advanced Reinforced Concrete Design	3
CE 202	ET 204, ET 205	Prestressed Concrete Design	3
CE 203	ET 204, ET 205	Structural Dynamics and Earthquake Engineering	3
M.Eng'g. in Mechanical Engineering: Heat Transfer, Thermodynamics and Energy Systems (12 units)			
ME 200	ET 204, ET 205	Combustion Engineering	3
ME 201	ET 204, ET 205	Thermal Engineering	3
ME 202	ET 204, ET 205	Two-Phase Flow and Heat Transfer	3
ME 203	ET 204, ET 205	Thermal Science Application in Power Engineering	3
M.Eng'g. in Electrical Engineering Major Courses: Power Engineering (12 units)			
EE 200	ET 204, ET 205	Power System Operation & Controls	3
EE 201	ET 204, ET 205	Power Transmission and Distribution	3
EE 202	ET 204, ET 205	Computer Applications in Power Systems	3
EE 204	ET 204, ET 205	Renewable Energy Resources Design	3
M.Eng'g. in Electronics Engineering: Robotics and Control Engineering (12 units)			
ECE200	ET 204, ET 205	Electronic Systems and Instrumentation	3
ECE201	ET 204, ET 205	Robotics and Mechatronics Engineering	3
ECE202	ET 204, ET 205	Modern Control Systems	3
ECE203	ET 204, ET 205	Digital Control Systems	3
ET 210		140 HOURS Industry Immersion	3
		Comprehensive Exam	
ET 211		Thesis Writing	6
		Total Units	**48**

4.4 Integrated curricula using the CDIO framework

From the results of the survey, the top five industry expectations are multidisciplinary teamwork, advanced engineering fundamental knowledge, methods and tools, attitudes, thought and learning, ethics, equity and other responsibilities, and communications. Multidisciplinary teamwork, attitudes, thought and learning, and communications were integrated into the developed curricula. Communications will be taught (T) in the course engineering research and development.

While the multidisciplinary teamwork, and attitudes, thought and learning will be used (U) and be assessed (A) in the various courses of the program as shown in the integrated curriculum. Course syllabi on these courses should be designed and incorporated the various skill-sets as presented in the curriculum.

The foundation courses serve as the fundamentals of engineering as stated in standard 4. Four major courses were incorporated in the curriculum to enhance the implementing skills along with Design & Build experience (standard 5). Figures 1 to 3 shows the gap analysis, skill map and full integrated curriculum.

CDIO SKILLS GAP ANALYSIS Revision Date: November 5, 2018

University Name: CAMARINES SUR POLYTECNIC COLLEGES Faculty Name: COLLEGE OF ENGINEERING

Program Name: MASTER OF ENGINEERING Program Coordinator Name:

Year / Semester	Course (Subject) Name	CDIO 3.1: Multidisciplinary Teamwork				CDIO 2.4: Attitudes, Thought and Learning				CDIO 3.2: Communications Communication			
		Status	Explicitly Teach (Y/N)	Use (Y/N)	Assessed (Y/N)	Status	Explicitly Teach (Y/N)	Use (Y/N)	Assessment (Y/N)	Status	Explicitly Teach (Y/N)	Use (Y/N)	Assessment (Y/N)
Year 1 Sem 1	Engineering Research and Development									B	N	Y	Y
	Probability & Statistical Concepts												
	Advanced Engineering Mathematics 1												
Year 1 Sem 2	Computer Engineering												
	Advanced Engineering Mathematics 2												
	Numerical Methods												
Year 1 Sem 3	Computer-Aided Design Applications												
	Production Eng'g. & Management												
	Environment, Energy & Tch. Mngt.												
	Major Course 1												
Year 2 Sem 1	Major Course 2												
	Industry Immersion	B	N	Y	Y	A	N	Y	Y	L	N	Y	Y
	Thesis 1					A	N	Y	N	A	N	Y	Y
Year 2 Sem 2	Major Course 3												
	Major Course 4												
	Thesis 2					A	N	Y	N	A	N	Y	Y

Use the following symbols for "STATUS"

B CDIO Skill reflected in Learning Outcomes and Learning Activities

L CDIO Skill reflected in Learning Outcomes but NOT Learning Activities

A CDIO Skill reflected in Learning Activities but NOT Learning Outcomes

Fig. 1. Current Gap Analysis

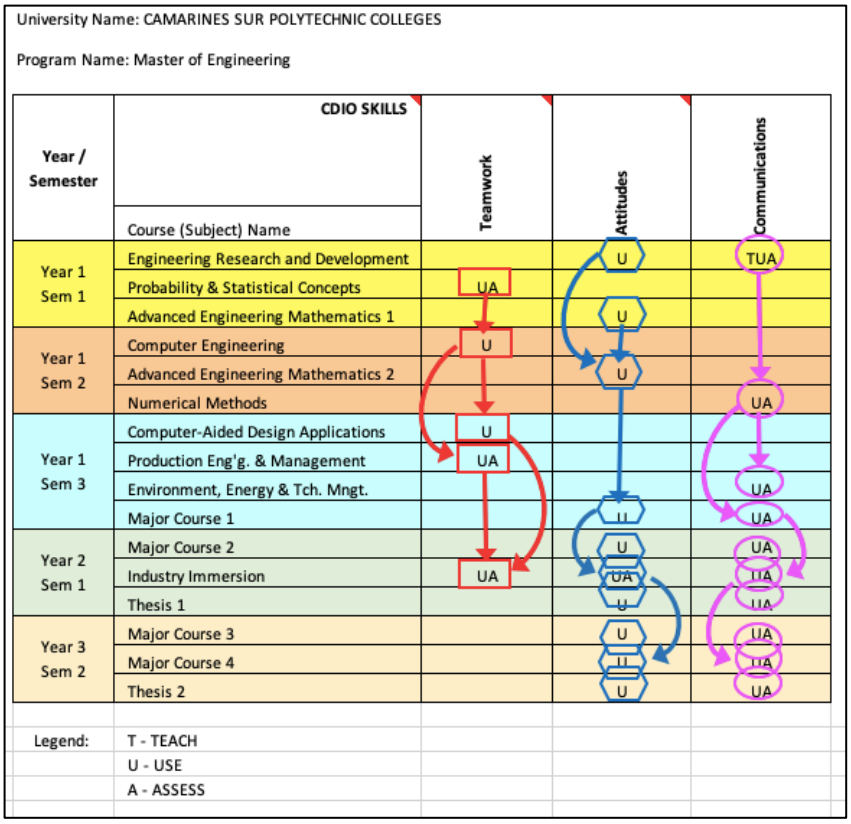

Fig. 2. Skill Map

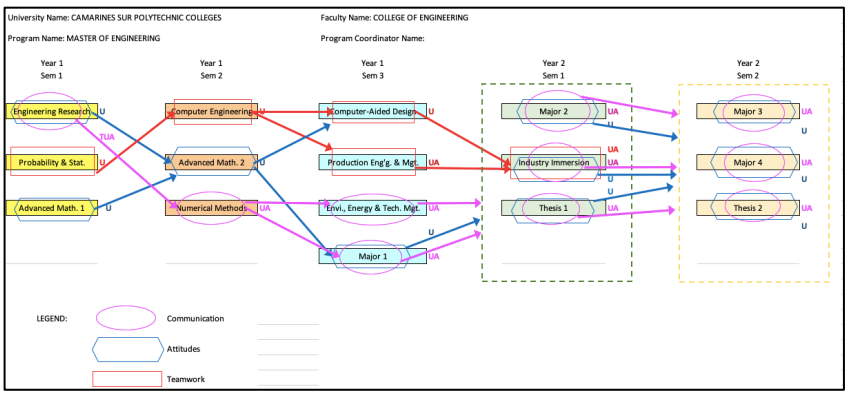

Fig. 3. Integrated Curriculum (Same for the Four Programs)

5 Conclusion and Recommendations

The developed integrated curricula for the master of engineering programs using CDIO framework conforms with the current educational standards in engineering education. The contents of the curricula were revised. Graduate attributes were developed, and the industry needs survey was conducted as bases in the integration of various skill-sets and attributes of graduate students. Multidisciplinary teamwork, attitudes, thought and learning, and communications were integrated into the curricula. Policies regarding admission, industry immersion, comprehensive examination, thesis/research, and other academic-related policies on the master's degree in engineering which are not part of this study can be developed based on the approaches of the CDIO framework. The developed curricula can now be in the process for approval with the academic council for implementation. Stakeholder's validation will be essential to determine the effectiveness of the developed curricula. Faculty professional and teaching enhancement will lead to a successful implementation of the developed curricula.

6 Acknowledgement

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7 References

[1] Campbel, B.R., Voelker, J.J., and Kremer, C.S. (2015). An analysis of engineering educational standards and outcomes achieved by a robotics summer camp experience. *International Journal of Engineering Pedagogy, 5(4),* 12-21. Retrieved from www.online-journals.org. Accessed on November 6, 2018. https://doi.org/10.3991/ijep.v5i4.4713

[2] About CDIO. (n.d.). Retrieved from http://www.cdio.org/about. Accessed on August 7, 2018.

[3] Mammi, H.K. and Ithnim, N. (2012). Competency based education (CBE) for IT security: towards bridging the gap. *International Journal of Engineering Pedagogy, 2(4)*, 24-26. Retrieved from www.online-journals.org. Accessed on October 4, 2018.

[4] Philippine Batas Pambansa 512 Section 2.

[5] Camarines Sur Polyetchnic Colleges (CSPC), Available: http://cspc.edu.ph/academics/college-of-engineering/ Accessed on September 10, 2018.

[6] Wah, C.K, Tan, D. and Wee K. S. (2015, June 8-11). *CDIO and ABET accreditation-the Nanyang Polytechnic Experience.* Paper presented at the 11th International CDIO Conference, Chengdu University of Information Technology, Chengdu, Sichuan, P.R. China.

[7] Campbell, D., Dawes, L., Beck, H., Wallace, S., and Boman, M. (2009, December 6-9). *Graduate attribute mapping with the extended CDIO framework.* Paper presented at the 20th Australasian Association for Engineering Education Conference 2009.

[8] Chuchalin A. I., Petrovskaya, T. S., Kulyukina, E. S., and Tayurskaya, M. S. (2012, July 1-4). *Benchmarking of TPU academic standards and CDIO standards in engineering education.* Paper presented at the 8th International CDIO Conference, Queensland University of Technology, Brisbane.

[9] CDIO Standards 2.0. (n.d.). Retrieved from http://www.cdio.org/implementing-cdio/standards/12-cdio-standards https://doi.org/10.12737/5875

[10] CDIO Syllabus. (n.d.), Retrieved from http://www.cdio.org/framework-benefits/cdio-syllabus https://doi.org/10.21125/iceri.2016.0393

[11] F Crawley, Edward & Malmqvist, Johan & Lucas, William & R Brodeur, Doris. (2011, June 20-23). *The CDIO syllabus v2.0: an updated statement of goals for engineering education.* Paper presented at the 7th International CDIO Conference, Technical University of Denmark, Copenhagen.

[12] F Crawley, Edward & Malmqvist, Johan & Lucas, William & R Brodeur, Doris. (2011, June 20-23). *The CDIO syllabus v2.0: an updated statement of goals for engineering education.* Paper presented at the 7th International CDIO Conference, Technical University of Denmark, Copenhagen.

[13] Crawley, E.F. (2001). *The CDIO syllabus: a statement of goals for undergraduate engineering education.* Available: http://www.cdio.org/files/CDIO_Syllabus_Report.pdf \ Accessed on September 22, 2018. https://doi.org/10.1109/fie.2002.1158202

[14] Kuptasthien, N., Triwanapong, S., and Kanchana, R. (2016). Integrated curriculum development in industrial engineering program using CDIO framework. *Communications, 3,* 30-37. Retrieved from http://aeer.ru/filesen/io/m16/art_3.pdf. Accessed on October 10, 2018.

[15] Paul, R., Hugo, R. J. and Falls, L. C. (2015, June 8-11). *International expectations of engineering graduate attributes*. Paper presented at the 11th International CDIO Conference, Chengdu University of Information Technology, Chengdu, Sichuan, P. R. China.

[16] Kuptasthien, N., Triwanapong, S., and Kanchana, R. (2016). Integrated curriculum development in industrial engineering program using CDIO framework. *Communications, 3,* 30-37. Retrieved from http://aeer.ru/filesen/io/m16/art_3.pdf. Accessed on July 18, 2018.

[17] Ercan, M.F., Sale, D. and Kristian, N. (2016). Innovative curriculum to enhance the learning experience of electrical and mechanical engineering students. *International Journal of Engineering Pedagogy, 6(3),* 37-44. Retrieved from www.online-journals.org. Accessed on November 21, 2018. https://doi.org/10.3991/ijep.v6i3.5765

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Empowering Talented Students:

An Italian Experience of an Enriched Curriculum in Engineering

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Abstract—This paper summarizes the design, the activities performed, and the main results achieved by an innovative teaching program, set-up for the talented freshmen in Engineering Bachelor's courses at an Italian technical University, the Politecnico di Torino, starting from 2013.

The project structure is here detailed, year-by-year, with a focus on both the reinforcement of an Engineering standard curriculum, and the hybrid activities, also in non-technical areas, such as soft-skills, critical thinking, humanities, and creativity. The strategies and methods for the students' selection are discussed, and the University human resource efforts and the costs involved are justified. The results achieved during a three-year experience, based on a structured survey to collect students' feedback, are then critically analysed with the purpose to suggest implementation and further development.

Keywords— Top Bachelor Students; Action Research; Reverse Inclusion Process; Hybrid Learning; Soft-Skills

Abbreviations—Academic Year (a.y.); Action Research (AR); Research Centre of FIAT (CRF); FCA (Fiat Chrysler Automobile); Politecnico di Torino (PoliTo); Talented Student (TS); Test in Laib (TIL).

1 Introduction

The Politecnico di Torino, from now on referred to as PoliTo, is an Italian Technical University with Engineering and Architectural schools. Like the whole Italian university system, it undergoes to the Bologna process regulation that requires a Bachelor lasting three years and a Master of Science lasting two years. In order to obtain a degree, a student needs to acquire 180 ECTS during the Bachelor program and 120 ECTS for Master. The academic year (a.y.) is divided into two semesters and each subject has two calls in the exam section right after the classes end. Moreover, there are two recovery calls, one at the end of the other semester, and one in September. An exam is passed if the score is higher than 18/30; the maximum obtainable score is 30/30.

The admission to a PoliTo Bachelor program is made by a computer-based test called "Test in Laib" (TIL), as Laib is a computers' laboratory. The test, which has demonstrated to well predict students' career, is investigating their knowledge in 4 sections: Comprehension, Logic, Mathematics, and Physics [1]. During the orientation pre-test phase, potential students can make use of support materials in order to prepare themselves for the admission, such as online materials and recorded lessons.

The quality of the preparation of our graduates is a fundamental objective, inherent to the University's mission. The graduated students in fact represent a precious output of the University and involve a relevant investment from the entire country. It is obvious that, on a subjective level, a well-trained graduated student gains an advantage in the labour market which - due to globalization - is more and more wide and competitive.

The present paper is aimed to describe the design, the activities performed, and the main results achieved by an innovative teaching program addressed to the Talented Students (TSs): "Research among Quality - Young Talent program" (La Ricerca della Qualità - Percorso per i Giovani Talenti). The project was oriented to both Engineering and Architecture areas, however, here we focus only on the Engineering Area which is more innovative. With the expression "Talented Student" we refer to a bright and clever learner who stands out in STEM subjects compared to classmates as resulting mainly during the selection performed by TIL.

In the following sections, the general context is described (Section 2) in order to highlight the research questions (Section 3). In Sections 4 and 5 the theoretical framework and the methodology are settled, respectively. Section 6 explains the findings, while Section 7 presents a wrap-up conclusion.

2 Context

In the university field, the new didactic frontiers have been only partially integrated with the classical learning methodologies, especially in technical schools. Unlikely the European and global trend, PoliTo is experiencing exponential growth of students [2] [3]. Consequently, the teacher/student ratio, currently about 1:35, is progressively decreasing, and one of the related drawbacks may be a less effective teaching performance, mainly penalising the protégé students. For this reason, the strengthening of a policy of inclusion towards protégé students has been favoured with the creation of support strategies in order to enable all students to reach an adequate level of knowledge and to complete their studies [4] [5] [6] [7] [8]. There are, in the Italian panorama, numerous and various attempts of inclusion and support in favour of students with greater difficulties.

It is not usual to stimulate the personal skills of each student in a differentiated and targeted manner by creating varied parallel paths with different levels of study on the same topic. Historically, the course of study is structured with a unique curriculum depending on the chosen mayor of interest. Starting from an analysis of the concept of teaching inclusion in the university it can be seen how its recent reversal, which means inclusion and support to the most capable and bright students for a renewal of teaching methods and contents, leads notably advantages to the entire university community and in particular to "weak" students [9].

Addressing this concept of high-level cognitive skills in High School Education and in University is a complex task, nowadays not successfully implemented in order to engender these skills in the students' curricula [10].

According to Jamison, Kolmos, and Holgaard, there are currently different perspectives regarding the role of the engineer as someone able to "transfer and translate scientific knowledge in practical application", as well as to create innovation and public service [11] [12]. These perspectives have a direct impact on curriculum development and teaching methods, in particular, the non-technical areas need to be reinforced and emphasized [13] [14] [15] [16]. As a consequence, hybrid learning is developed by a combination of scientific and non-technical activities that improve soft-skills, problem-solving, problem-setting and critical thinking, humanities knowledge, and creativity [12].

Furthermore, the enrichment of the curriculum with soft transversal skills, defined as "skills, values and attitudes that are required for learners' holistic development and for learners to become capable of adapting to change" [17], promotes the student's autonomy by increasing awareness of his/her cognitive processes. If a mentorship related to the development of lateral thinking is correlated to this metacognitive path to increase the effectiveness of learning, each student finds him/herself stimulated in a diversified manner and is able to reach an adequate knowledge with respect to his/her own abilities [18] [19].

Starting from the 80s, different attempts were made in order to enhance creativity and innovation [16] [20], that is, the identification of best practices such as:

- **Academic-Industrial liaison** – A Japanese example of a slender system;
- **Project training methods** – An integrated approach that includes complementary subjects, teaching design methodologies, and working groups;
- **Innovation centre and entrepreneurship strategy** – A way to be exposed to technology incubators, entrepreneurial projects and to interact with business and industry.

In a technical university, a professor has the responsibility of governing the learning processes. With teaching skills, the lecturer must capture the learners' attention to promote knowledge of learning processes, as well as the content itself. Therefore, the target will move to the educational scheme [21] [22].

In order to analyse the effect of the different schemes, a study in higher learning institution in South Africa has been performed among 118 physical metallurgy students in an engineering course. During the study, the information regarding peer learning, intrinsic and extrinsic motivation, help-seeking, and deep and surface learning with structured questionnaires have been collected. Generally, the group of students who receive an active learning approach to the subject scored higher than the one attending the traditional lessons on all variables except extrinsic motivation. This study strongly highlighted a significant positive relationship between deep learning and academic performance in the final model [23].

However, there are very few examples of creative, innovative and active teaching application inside a structured Bachelor technical school. For example, the Gibbs' find-

ings on 35 students of Economics attending the "learning to learn" program have highlighted a correlation between bright students and a high awareness of cognitive strategies and related processes [24] [25].

In Italy, there are few examples of reinforcement action in favour of bright students, but they regard in particular Master level and non-Technical University. Since ten years PoliTo, together with the Politecnico di Milano, has driven the experience of the "Alta Scuola Politecnica (ASP)", a Master path dedicated to talented students that offer workshops and training weeks [26].

If we consider Engineering Undergraduate Schools only, such innovative paths are almost absent. Typically, this curriculum reinforcement is managed by a Collegium, like the S. Anna School of Advanced Studies (Pisa) [27] and the Galilean School of Higher Education (Padua) [28], that create a parallel path in addition to a traditional public university. In both cases, however, the number of students involved is very limited (about 20 units each) compared to the overall student population in the local public universities and the paths provides only supplementary and in-depth complements in addition to the standard lessons that students must follow at the local public university. Moreover, these organizations offer at the end of the program a certificate, not a diploma degree.

A previous isolated attempt in the Engineering area organized by a public university was carried out by the Politecnico di Milano from the a.y. 08/09 until the a.y. 13/14. Also, in this case, however, the so-called "ASPRI" program was dedicated to the curricular reinforcement of some subjects. The program was then closed probably due to lack of interest from students.

3 Research Questions

Starting from the indispensable assumption of the absolute centrality of the student, for many years PoliTo has promoted a series of services and specific initiatives in favour of students to follow them on their educational path.

Much has been done with regard to the provision of the services themselves, which are highly computerized to streamline the procedures, ensuring a continuous and updated flow of information.

Among the teaching support initiatives to help the transition from a High School to a University, PoliTo offers various, particularly relevant, services including:

- Realignment online courses, before entering the university, for students who have specific gaps in Mathematics and Physics emerged from the admission test in order to allow them to face the first semester lessons with a more solid base knowledge
- Recovery courses dedicated to students who did not pass the first exam in Mathematics
- Recorded lessons made available online
- Tutoring assistance

With this in mind, it becomes clear that we need to keep focusing on the quality of students' preparation and to address specific action for another segment of the students'

population, that is the more skilled one. Considering all the new didactic potentials and the social requirements it is fundamental for a technical university to investigate and experience a new way to reinforce the learning processes starting from the Bachelor's years.

The research questions addressing this challenge can be stated as:

- How can a technical university properly support talented students? Can this process be inclusive without entirely separating them from the others?
- Do those actions impact on the rest of the students' population (i.e. students with some difficulties and students with normal career trend)?

4 Theoretical Framework

Teaching has long been understood as an operational part of pedagogy. Today, however, it arises as an autonomous science that studies the conditions of a space pedagogically understood, in which lecturers and students interact [29] [30].

Following this new vision, several studies were born to model and enrich the educational landscape. These were the most significant results [31] [32]:

- The concept of **inclusive education**, able to reach all the subjects in the "pedagogical" space;
- The concept of **metacognition**, with the aim of bringing the students, with due solicitations, to the awareness of their choices. This requires developing the ability to reflect on what happens during the learning process and on the related most suitable strategies [33] [34];
- The formalization of the **traditional model** consisting of a student's modelling (imitative process), coaching (systematic teacher assistance), scaffolding (deepening and stimulation), and fading (gradual reduction of teaching support);
- The **mentorship technique**, which implies guided learning between an experienced subject (mentor) and one with less experience (protégé) [35];
- The **cognitive learning model** made up of the articulation or the exposition of the experiences of the students, from the reflection or growth in the comparison with a senior expert and from the exploration or new vision of the problems and related solutions.

In order to address the research questions above, the Action Research (AR) theory has been identified as the correct framework to use. This research strategy is used to solve a practical problem and to produce guidelines for best practice [36]. The theory has been developed by Kurt Lewin and he described it as "a comparative research on the conditions and effects of various forms of social action and research leading to social action" [37]. The AR can be seen as a looped cyclic set of inquiry: planning, action, finding, reflection, and identification of improvements. Nowadays, this practical investigation is frequently adopted in the educational field in order to develop and test new projects and experimentations [38].

5 Methodology

For this Bachelor project, we aim to merge both humanistic and technical profiles in order to reinforce the regular study by applying the hybrid learning philosophy. This fulfils the social skills' requirement by enriching the competences' framework with critical thinking and soft skills aptitudes such as teamwork and team building.

To answer the research questions, we decided to develop the Talented Students (TSs) program integrated with the standard curriculum by the use of an AR. The structure of the AR is organized into five steps: (1) Plan and Exploration, (2) Act, (3) Observe, (4) Reflect, (5) Specific Learning and Improvement. Each step includes different activities, as shown in Fig. 1.

Fig. 1. Action Research cycle in detail

Plan and exploration started in September 2013 with the first call open for the a.y. 14/15. The aim of the project was to design a program in order to favour bright students and to raise the overall quality of learning among all the students' population. After the definition of the context, aims, boundaries of the program, and review of existing experiences in a similar context, we decided to select around 200 incoming students. We

chose a project structure that for a limited extent separates the talented students from the others for the entire duration of the Bachelor program.

Then, the first selection took place and the program started its first edition. In order to implement the "observe" and "reflect" stages, a structured qualitative questionnaire with scale 1 to 5 answer has been prepared and submitted to the students at the end of each academic year. The descriptor used are listed and detailed in Tab. 1.

Table 1. List of questionnaire descriptors with the related extended question

Descriptor	Related question
Homogeneous class goodness	Did the homogeneous class have a good effect?
Prof. theory exemplification	Did the professor properly exemplify the theory?
Prof. interest generation	Did the professor generate interest about the subject topic?
Prof./Expert clearness expository	Was the professor/expert clear in his/her exposition?
Effectiveness	Was the course effective?
Inherent activities	Did you feel that the activities were inherent with the program?
Anticipation difficulties	Did you find it difficult the anticipation of Maths Analysis II?
Training class and Lab usefulness/goodness	Did you find the training class and labs section useful/good?
Positive experience	Do you think it was a positive experience?
Team building	Was it useful for team building?
Organization	Was it well organized?
Enrich skills and knowledge	Was it useful to enrich skills and knowledge?
Lab. Organization	Were the laboratory sections well organized?
Lab. Involvement	Did you feel involved in the laboratory sections?
Lab. Participation	Did you take part in the laboratory sections?
Interesting/understandable/useful	Do you think the activity was interesting/understandable/useful?
Fulfilled expectations	Did the activity fulfil your expectation?
Improve knowledge	Did you improve your knowledge?

5.1 Structure of the program

The selected students, during the three years, have a curriculum that combines the standard path with some dedicated activities, that is a mixture of courses and different hybrid activities. The detailed program is schematized in Fig. 2.

The project foresees the common attendance with all the other students, for the first-year courses (Chemistry, Computer Science, Mathematical Analysis I, Linear Algebra and Geometry, and Physics I). The standard courses are managed with parallel classes of around 250 students each. During the first semester reinforcement on the two curricular courses of Chemistry and Mathematical Analysis I are organized. The aim of these reinforcements is to provide a more organic, practical approach to the laboratory sections and an in-depth view of the topics covered, above all by stimulating a more au-

tonomous study. The interventions also aim at enhancing interdisciplinary themes. During the second semester, in advance with respect to the regular timing, the student must follow a reinforced course of Mathematical Analysis II. This in-depth teaching will be given to a homogeneous class, as well as Physics II that is taught in the third semester.

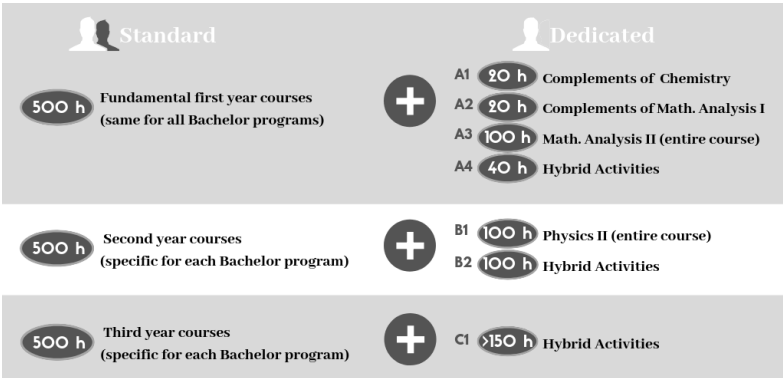

Fig. 2. The detailed structure of the program

The hybrid activities are a core element of the program and, for this reason, they are present each year of the curriculum. In fact, the main focus of the program is to apply the concept of hybrid learning by training students also in non-technical areas. This approach has a gradual increase year by year: it starts with few daily and weekend activities during the first year, it is organized in activities lasting weeks during the second year, and finally it covers a full semester in the third year.

More in details, as soon as the program begins, in November, the first seasonal weekend is organized. It consists of a three-days full-immersion activity, during which students are trained through seminar classes in order to generate a creative approach in solving practical exercises, a problem-solving competition in small teams, and activities such as hiking in the woods for educational purposes. Usually, the training weekend is organized in a remote small town in the mountains. This is an activity strategically inserted at the beginning of the path to allow students to get to know each other and start working in teams.

During the second semester, a guided visit to the CERN in Ginevra is organized to meet scientists and to discover the organization and management of an innovative research centre.

During the second year, in order to strengthen the linkage with the local industrial stakeholders, some visits to manufactory plants of famous companies, such as Maserati, are organized as well as some laboratory sections inside a FCA (FIAT Chrysler Automobiles) factory in Turin. This laboratories' activity is performed in small groups in which each student has the chance to reinforce labour knowledge. The experience is articulated in a two-hour plenary session dedicated to the presentation of vehicle development, the production processes, the main automotive research objectives of the coming years and open discussion. Following the plenary session, there are six different thematic sessions of 4/8 hours in a laboratories at the Research Centre of FIAT (CRF).

For the practical experience, each student can choose the subject among: crash FEM analysis, computational fluid dynamics, electromagnetic compatibility, powertrain development, smart materials, and cooperative and wearable robotics. Students are given the opportunity to choose one of the proposals and deepen a phase of the R&D process in close contact with FCA and CRF engineers and technicians.

During the third year, students are divided into small groups to follow different activities:

- **Study abroad** - Students can spend a semester of study abroad. The aim is to encourage the possibility of training experiences abroad thanks to large network agreements with other universities;
- **Interdisciplinary project** - Projects with a concrete social impact, related to the improvement of the local environment in collaboration with public administrations;
- **Seasonal Schools** - Different kinds of learning full-immersion are proposed in order to reinforce specific knowledge;
- **Internship** - A period of work experience inside important and innovative local factories.

Then, special events and dedicated conferences are organized as well. For example, a cycle of conferences, named "Building up the future", concerns not only relevant scientific issues but also humanistic topics such as philosophical implications in science, history of technological evolution, adaptability to change and ethical problems. In the meantime, dedicated meetings are organized with important international CEOs and top managers to understand the current work environment and to head off innovative challenges.

The hybrid activities, whose IDs are defined in Fig. 2, can be directly related to the skills acquired as shown in Tab 2.

Table 2. Skills assessments activity by activity

ID activity	Teamwork	Team building	Responsibility	Motivation to career	Research awareness	Decision making	Leadership	Result orientation	Problem-solving	Organization	Critical thinking	Technical
A1	x									x	x	x
A2										x	x	x
A3	x									x	x	x
A4	x	x	x	x	x	x	x	x	x		x	
B1								x		x	x	x
B2	x	x		x	x						x	x
C1	x	x	x	x	x	x	x	x			x	x

The students are placed side by side of mentors who will not only strengthen their knowledge, as the typical role of the tutor requires, but will also be able to broaden the cultural background, foster personal growth and integration in the group through the

transfer not only of technical knowledge but also of professional experience and labour market skills.

Students who join the program will receive not only a didactical motivation but also some economical and welfare advantages as well as a special certification.

In order to get the "Progetto Talenti" diploma, a student needs to fulfil the requirements until the end, to take part to all the activities required and must graduate on time (until December of the third year of the Bachelor path).

At Polito, the tuition fees are proportional to the family income ranging from no tax area to a maximum of around 2,800 euro. Considering this taxes distribution, all the students of the program are exempted from taxes if the amount due is less than or equal to 1,500 euro, while if it is higher, students have a tax reduction of 1,500 euro.

Finally, students receive a package which includes the local transportation subscription (Bus and Bike sharing), and a card for free access to many regional museums.

5.2 Structure of the selection process

By looking at the PoliTo incoming population in the last couple of years we were able to highlight a group of talented students transversal to all the Engineering programs. In particular thanks to the strong correlation between the TIL admission test score and the student career, the TIL score behaved as a good selection instrument [1].

Considering the whole community of freshmen, students who have obtained a score equal to or greater than 70/100 are around 7% of the approximately 5,000 students attending the test (Tab. 3). Students belonging to this set are the ideal candidates for the project.

Table 3. Distribution of the number of students considering their TIL's score per a.y.

Score range	11/12		12/13		13/14	
- 9.99	214	1319	220	1880	276	1372
10 - 19.99	396		541		383	
20 - 29.99	709		1119		713	
30 - 39.99	805	1479	1275	2323	870	1856
40 - 49.99	674		1048		986	
50 - 59.99	541	956	548	891	956	1548
60-69.99	415		343		592	
70 - 79.99	191	278	140	234	299	456
80- 89.99	75		73		123	
90- 100	12		21		34	
Total	4032		5328		5232	

Although the language of this first experiment is Italian, the program is open to all students, both national and international ones, requiring, however, a basic knowledge

of the Italian language, while the common courses can be followed either in Italian or in English.

The number of participants is amounting to around 4% of the total (over the approximately 4,500 students enrolled).

In order to remain in the program, the students need to fulfil some requirements year by year. In particular, there are the following checkpoints:

- End of the first semester
- End of the first year
- End of the second year
- End of the third year

In the event that the student does not meet the requirements, he/she will continue the studies on the regular path. In the meantime, maintaining the requirements of the maximum enrollment of 4% of the total population (around 200 seats), it is possible to include new students into the program during the first two checkpoints listed above.

5.3 Resources planning

The design has been articulated in high-level governance, medium level or management, and low level or planning and execution.

A commission of 6 components, including a representative student, has been appointed in order to define the whole structure of the path. The board meets once a month to approve all the different activities and project works.

The main objects of the commission are planning of the yearly program contents, selection of the teaching staff, tutors and mentors, monitoring the program quality, and definition of the budget.

For the management level, two administrative technical persons were seconded to full-time.

In Tab. 4 the Human Resources, as a Full-Time Equivalent (FTE) effort, necessary for the yearly implementation of the project, are summarized.

Table 4. Resource effort in term of Full-Time Equivalent

Typologies	Number FTE
Management staff	1
Administrative staff	2
Teaching staff	7
	(5 Academics and 2 Industrials)

The economic framework of the project takes into account the costs necessary for its implementation and maintenance over time.

The project involves a series of ad hoc expenditure items as the creation of a specific three-year path that goes alongside the standard pathways; in particular, it includes:

- Lower income from the registration fees due to the total or partial exemption
- An increase in the number of teaching hours

- Organization of seasonal schools and related teaching hours
- Mobility grants
- Ad hoc management and monitoring of the enrolled students' career
- Tutoring and mentoring.

In order to cover partially these extra costs an agreement between PoliTo and the CRT Foundation, a Torino private banking foundation, has been signed.

6 Findings

6.1 Quantitative analysis

In September 2014 the first students' selection took place and the program started engaging 191 students. The gender ratio is of 86% male and 14% females. Around the 30% of students come from Piedmont (the Region in which PoliTo is located), 15% from Apulia, 12% from Sicily, and the remaining part is equally distributed among all the other Italian regions and several foreign countries.

Looking at the TIL score of the TSs of each cohort, the general trend is growing as shown by boxplot in Fig. 3. It is clearly visible that, not only the average score is increasing year by year, but the overall quality of the enrolled students has improved. Hence, as it can be seen in Fig. 4, the number of whole freshmen reaching TIL scores higher than 70/100 referred to the overall freshmen is significantly increasing. In the meantime, also the number of students graduating in 3 years and within 3.5 years keeps incrementing.

Following the direction described in the above section, considering the first three cohorts, the number of students in the program becomes more stable, as it can be observed in Fig. 5. In addition, we can notice that in the first cohort the 83% of TSs obtain the "Talenti" diploma.

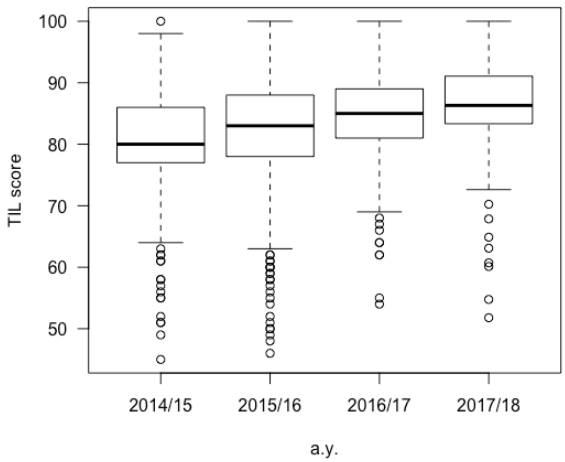

Fig. 3. Boxplot of the TIL score related to students of each cohort

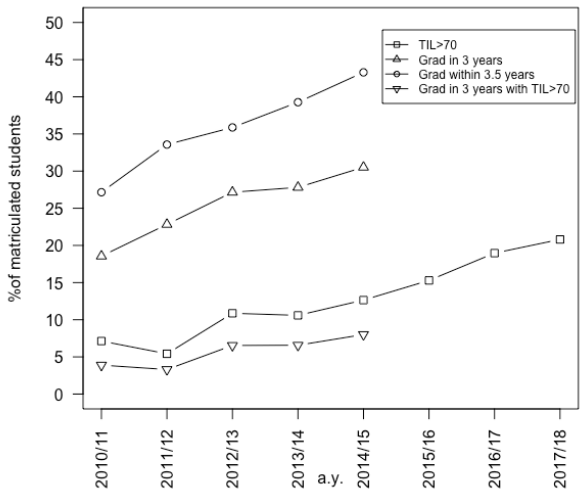

Fig. 4. Percentage distribution of overall matriculated students based on enrolled ones and of students with TIL score higher than 70/100

Speaking about the continuation of studies, all TSs continued their studies. Considering the 158 students graduated with the "Progetto Talenti" diploma, 124 of them applied to a Master of PoliTo, while 34 students continued their studies in European Universities with ranking higher than PoliTo. For example, 11 of them were admitted at the EPFL, 4 at the ETH and 4 at TU Delft. In the meanwhile, 25 TSs have been accepted at the ASP [26].

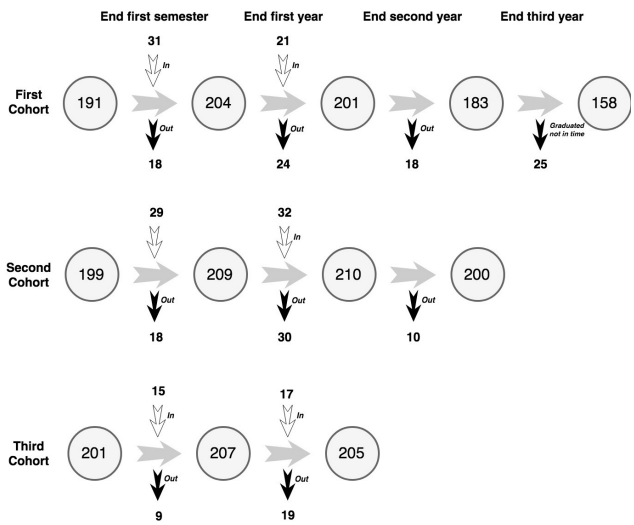

Fig. 5. Number of students involved step-by-step (in the circles), entering (white arrows) or leaving (black arrows) the program

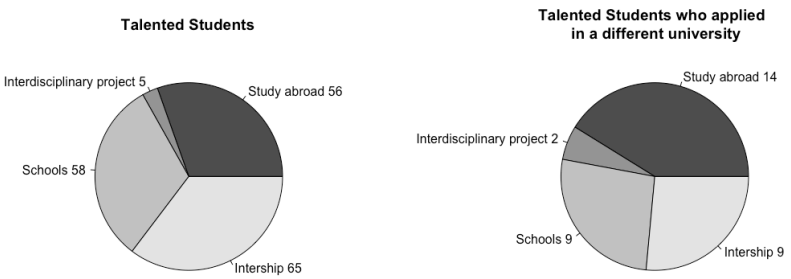

Fig. 6. Analysis of third-year activities selection by the overall talented students (right) and the ones that applied in a different university (left)

A possible correlation between the hybrid activities chosen during the third year and the studies prosecution has been analysed, but no direct influence has been highlighted (Fig. 6).

6.2 Qualitative analysis

Thanks to the data collected by the structured survey, an analysis of the students' feedback has been conducted. To date, we have collected the data from three cohorts of students for the first year of the program, two cohorts for the second and one for the third one.

The first-year survey is made of 20 questions corresponding to a level of satisfaction between 1 and 5, and an additional optional comment box. Fig. 7 shows a graphical representation of the results. Inside the comment box, the students give suggestions and observations about all the activities' organization and content. Almost 25% of students of the first cohort underline an unbalance weight between the first and the second semester and almost 20% report the importance of the laboratory sections in the Chemistry reinforcement.

The second-year survey is made of 15 questions with a similar indication. Fig. 8 is a graphical representation of the results.

Based on the data and on the comments achieved, it is important to formulate some reflection on the course structure.

Considering the first year, all the courses and activities are well performing, and the prefixed skills have been acquired. However, the mentorship support has obtained very low evaluation score especially on the questions about its efficiency on solving doubts, interest generated and on the number of meetings. In fact, a very low percentage of students has been requested at least one meeting with their mentor. Therefore, for the following cohort, it has been deactivated. A generic tutor has been introduced as a reference for each year to reply all the questions inherent to the structural and the organization problems.

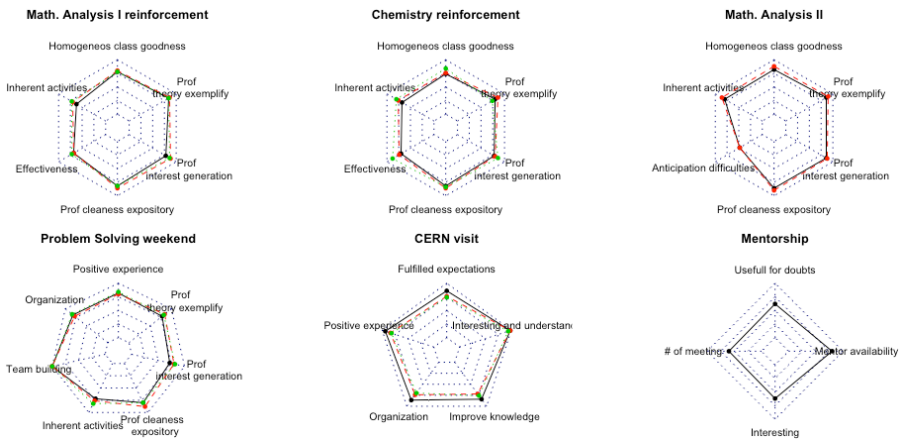

Fig. 7. Radar graph for each activity of the first year for the 3 cohorts

The first cohort of this program highlighted the importance of Chemistry's laboratory section in order to gain the correct technical knowledge. For this reason, starting from the a.y. 15/16, the laboratories sections inside the traditional Chemistry course have been enriched by a larger number of hours in lab ensuring, in the meantime, the access to all the students divided in smaller groups.

Looking at the Mathematical Analysis II survey's result, no special issues are reported about the anticipation of the course from the first semester of the second year to the second semester of the first year.

However, as the students suggest in their comments, the work-load is not well balanced between the two semesters. This leads to a more general reflection and reorganization on the standard path of the first-year courses. Considering the courses background requirements, the Computer Science course was the best candidate to be moved from the second to the first semester. Then, this course anticipation has been implemented to all the students starting from a.y. 16/17.

Fig. 8. Radar graph for each activity of the second year for the first 2 cohorts

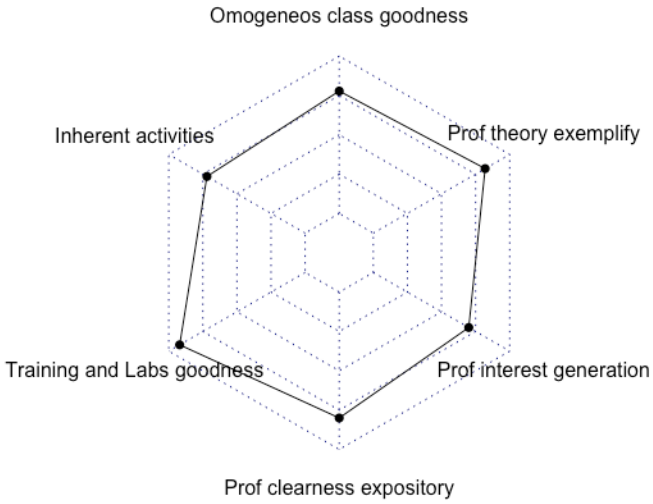

Fig. 9. Radar plot with the results of the Linear Algebra and Geometry course's survey

The standard Geometry class needed a review in term of contents with a reinforcement of the Linear Algebra part and the introduction of MatLab software, and a new course of Linear Algebra and Geometry has been planned. Instead of implementing this completely restructured course in the standard path, the trail test is made in a dedicated course for the TSs. In fact, students in the program can perfectly simulate the numerousness of a standard class and can help to judge the goodness of the new syllabus. The students have been giving good feedback about this new course (Fig. 9).

Thanks to this trial, the contents of the second semester courses has been arranged and, starting from a.y. 16/17, the new Linear Algebra and Geometry has been proposed to all the students in the traditional path instead of the previous Geometry course.

Another aspect that needs to be considered is the frequency of usage of benefits such as the Museum card, the Bike card and the Public transportation card. The use is very high for all the three services with the students' majority concentrated in the weekly/daily usage of the mobility cards and monthly of the cultural card (Fig.10).

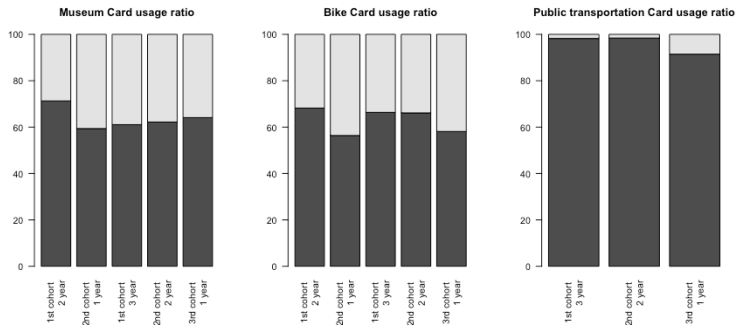

Fig. 10. Bar plot of the usage of each service year by year

As per the data collected, students find the Museum Card and the public transport subscription very useful. For this reason, starting from a.y. 17/18, these tools have been offered to almost all the students enrolled based on their career and their economic status.

7 Conclusion

The creation of this program facilitates TSs without the creation of a complete differentiated path. Students in the program foster hybrid imagination by gaining technical and soft skills that help them to fit the industrial world requirements [12]. Thanks to dedicated activities, like the problem-solving weekend, students become a cohesive group although they are not in the same courses. Moreover, they influence each other creating a very inspiring environment that affects also the standard courses.

Hence, the existence of this program highlighted that, by enriching the curriculum of around 200 students, the entire community gains different benefits and increase in quality. This phenomenon is been defined as "reverse inclusive processes", that is, "all the activities that, thanks to the mixed class formation, indirectly include the protégé students by stimulating and motivating the deserved ones" [9].

In particular, as highlighted by the "Reverse inclusion study", the program has already increased the overall quality of all the students and reduced their graduation time [9]. In addition, it is a precious opportunity for the possibility to experiment course improvements or modifications on a small and well responding class instead of letting the changes impact the overall community.

Considering the study continuation, all the TSs apply to a Master either in our institution or in another university. Those who decided to continue their studies in a different university chose a university with a higher ranking position than PoliTo.

In the end, the talented program seems to be well suited to answer the need of the university. The human and economical effort foreseen by its implementation is properly impacting, not only the TS ones but a larger audience.

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9 Disclosure Statement

Disclosure statement: No potential conflict of interest was reported by the authors.

10 References

[1] M. Ballatore, L. Montanaro and A. Tabacco, "TIL: an innovative tool for the recruitment of bachelor engineering students in Italy," International Education and Research Journal, vol. 4, no. 2, pp. 79-84, 2018.
[2] G. Viesti, Un rapporto sugli atenei italiani da Nord a Sud, F. Res, Ed., Napoli: Donzelli Editore, 2016.
[3] E. Prieto, A. Holbrook, J. O'Connor, A. Page and K. Husher, "Influences on engineering enrolments. A synthesis of the findings of recent reports." European Journal of Engineering Education, vol. 34, no. 2, pp. 183-203, 2009. https://doi.org/10.1080/03043790902835940
[4] N. Entwistle and P. Ramsden, Understanding Student Learning, London (England): Social Science Research Council, 1983.
[5] F. Marton and R. Saljo, "Approaches to learning," in The Experience of Learning, Edinburgh, Scottish Academic Press, 1984.
[6] J. Biggs, "Enhancing learning skills: the role of metacognition," in Student learning: Research into practice, Melbourne, he Marysville Symposium, Parkville: Centre for the Study of Higher Education, 1986, pp. 131-148.
[7] N. Enwistle, "Approaches to learning and perceptions of the learning environment: introduction to the Special Issue," Higher Education, vol. 22, pp. 201-204, 1991.
[8] J. H. F. Meyer and R. M. Watson, "Evaluating the quality of student learning," Studies in Higher Education, vol. 16, pp. 251-275, 1991.
[9] M. G. Ballatore, L. Montanaro and A. Tabacco, "Inclusion: a new reverse perspective," in To appear in UK & Ireland EERN Symposium Proceedings 2018, Portsmouth, UK, 2018.
[10] F. Monteiro, C. Leite and C. Rocha, "From the dominant engineering education perspective to the aim of promoting service to humanity and the common good: the importance of rethinking engineering education," European Journal of Engineering Education, pp. 1-15, 2018. https://doi.org/10.1080/03043797.2018.1435630
[11] J. D. Scott, "Learning Technological Concepts and Developing Intellectual Skills," in Shaping Concepts of Technology: From Philosophical Perspective to Mental Images, Dordrecht, Springer Netherlands, 1997, pp. 161-180. https://doi.org/10.1007/978-94-011-5598-4_13
[12] A. Jamison, A. Kolmos and J. E. Holgaard, "Hybrid Learning: An Integrative Approach to Engineering Education," Journal of Engineering Education, vol. 103, no. 2, pp. 253-273, 2014. https://doi.org/10.1002/jee.20041
[13] C. Didier and A. Derouet, "Social Responsibility in French Engineering Education: A Historical and Sociological Analysis," Science and Engineering Ethics, vol. 19, pp. 1577-1588, 2013. https://doi.org/10.1007/s11948-011-9340-9
[14] V. Clemente, R. Vieira and K. Tschimmel, "A learning toolkit to promote creative and critical thinking in product design and development through Design Thinking," in 2016 2nd International Conference of the Portuguese Society for Engineering Education (CISPEE), 2016. https://doi.org/10.1109/cispee.2016.7777732
[15] E. Petty, "Engineering curricula for encouraging creativity and innovation," European Journal of Engineering Education, vol. 8, no. 1, pp. 29-43, 1983.

[16] I. Badran, "Enhancing creativity and innovation in engineering education," European Journal of Engineering Education, vol. 32, no. 5, pp. 573-585, 2007. https://doi.org/10.1080/03043790701433061
[17] E. Care and R. Luo, "Assessment of Transversal Competencies: Policy and Practice in the Asia-Pacific Region," 2016. [Online]. Available: http://unesdoc.unesco.org/images/0024/002465/246590E.pdf. [Accessed 15 10 2018].
[18] M. Silva, B. Malheiro, P. Guedes, A. Duarte and P. Ferreira, "Collaborative Learning with Sustainability-driven Projects: A Summary of the EPS@ISEP Programme," International Journal of Engineering Pedagogy, vol. 8, no. 4, pp. 106-130, 2018. https://doi.org/10.3991/ijep.v8i4.8260
[19] P. Bychkov, I. Zabrodina, M. Netesova and C. Mapelli, "Game-Based Learning while Research Activities of Engineering Students," International Journal of Engineering Pedagogy, vol. 8, no. 4, pp. 153-161, 2018. https://doi.org/10.3991/ijep.v8i4.8126
[20] R. Tomkins, "Educating the engineer for innovative and entrepreneurial activity," European Journal of Engineering Education, vol. 5, no. 2, pp. 97-159, 1980. https://doi.org/10.1080/03043798008903509
[21] E. De Graaff and R. Wim, "Training complete engineers: Global enterprise and engineering education," European Journal of Engineering Education, vol. 26, no. 4, pp. 419-427, 2001. https://doi.org/10.1080/03043790110068701
[22] M. Pinho-Lopes and J. Macedo, "Project-Based Learning to Promote High Order Thinking and Problem Solving Skills in Geotechnical Courses," International Journal of Engineering Pedagogy, vol. 4, no. 5, pp. 20-27, 2014. https://doi.org/10.3991/ijep.v4i5.3535
[23] M. Tlhoaele, C. Suhre and A. Hofman, "Using technology-enhanced, cooperative, group project learning for student comprehension and academic performance," European Journal of Engineering Education, vol. 41, no. 3, pp. 263-278, 2016. https://doi.org/10.1080/03043797.2015.1056102
[24] G. Gibbs, Teaching Students to Learn: a student-centred approach, Milton Keynes: Open University Press, 1981.
[25] M. Romainville, "Awareness of cognitive strategies: The relationship between university students' metacognition and their performance," Studies in Higher Education, vol. 19, no. 3, pp. 359-366, 1994. https://doi.org/10.1080/03075079412331381930
[26] S. Benedetto, F. Bernelli Zazzera, P. Bertola, M. Cantamessa, S. Ceri, C. Ranci, A. Spaziante and R. Zanino, "Alta Scuola Politecnica: an ongoing experiment in the multidisciplinary education of top students towards innovation in engineering, architecture and design," European Journal of Engineering Education, vol. 35, no. 6, pp. 627-643, 2010. https://doi.org/10.1080/03043797.2010.505278
[27] Sant'Anna School of Advanced Studies, "Training Project," [Online]. Available: https://www.santannapisa.it/en/collegio/training-project. [Accessed 14 03 2019].
[28] Galilean School of Higher Education, "Main Features," [Online]. Available: http://www.unipd-scuolagalileiana.it/en/content/main-features. [Accessed 14 03 2019].
[29] R. Massa, "IV - Educazione e pedagogia nell'Età moderna," in Istituzioni di pedagogia e scienze dell'educazione, Bari, Laterza, 1994.
[30] I. Rosati, Lezioni di didattica, Roma: Ancia, 1999.
[31] A. Visalberghi, Pedagogia e scienze dell'educazione, Trento: Mondadori, 1990.
[32] R. Perrini, Pianeta Scuola. Dalla A come apprendimento alla V come valutazione, Roma: Armando, 2002.
[33] W. Brezinka, Metateoria dell'educazione, Roma: Armando, 1978.
[34] T. J. Perfect and B. L. Schwartz, Applied Metacognition, United Kingdom: Cambridge University Press, 2002.

[35] A. Lleò, D. Agholor, N. Serrano and V. Prieto-Sandoval, "A mentoring programme based on competency development at a Spanish university: an action research study," European Journal of Engineering Education, 2017. https://doi.org/10.1080/03043797.2017.1415298
[36] M. Denscombe, Good Research Guide: For small-scale social research projects, Berkshire, GBR: Open University Press, 2010.
[37] K. Lewin, "Action research and minority problems," Journal of Social Issues, vol. 2, no. 4, pp. 34-46, 1946.
[38] Glossary of Education Reform, "Action Research," Great Schools Partnership, [Online]. Available: https://www.edglossary.org/action-research/. [Accessed 2019 03 15].

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Executive Functioning and Problem Solving: A Bidirectional Relation

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Abstract—There is a bidirectional relation between one's executive functioning abilities and problem solving skills as they are both based on self-control. "Hot" and "cold" executive functions account for individuals' cognitive control and emotional regulation. In addition, problem solving is tied to metacognitive awareness processes, necessary for applying executive function skills in goal setting and decision making situations. Therefore, individuals' overall cognitive flexibility and emotional regulation can promote the quality, quantity and speed of decision-making processes, such as adaptable and creative information processing as well as efficiency in setting and prioritizing goals. Moreover, individuals with ADHD, Autism Spectrum Disorder, Oppositional Defiant Disorder and individuals with other comorbid states, such as older adults, individuals with Traumatic Brain Injury (TBI) can counterbalance their cognitive control deficits through enhancing their problem solving skills. In addition, an advanced research in the bidirectional relation between executive function and problem solving skills could develop a comprehensive methodology for training and assessing self-regulatory processes.

Keywords—Attentional processes, cognitive control, cognitive flexibility, emotional regulation

1 Introduction

"The definition of executive function usually includes the concept of controlling attention, mental flexibility, goal-directed behavior and the ability to anticipate the consequences of one's own behavior. Moreover, the concept of self-awareness and the idea that the frontal lobes serve as a manager and programmer of human psychological processes (metacognition) are also included in this definition" (Ardila, 2016)[1].

According to Ardila[2], there are two distinct subgroups constituting individuals' executive functioning; Metacognitive as well as Emotional/Motivational executive functions. Metacognitive executive functions refer to response inhibition, conflict monitoring and switching, self-awareness, temporality of behavior, self-consciousness, working memory, abstraction and problem solving.

Emotional/motivational executive functions entail the coordination of cognition and motivation as well as the ability to control emotions and behavior. Also, Jiang et al.[23] discriminated individuals' executive functions in "cold" and "hot". Petrovic et al.[22] initiated an integrated model of emotional and non-emotional, related networks with hierarchical perception-action organization tied to complex and temporally dispersed, information processing. Channon [20] referred to the independence of social cognition and non-social executive abilities.

By investigating the relation between one's cognitive/metacognitive skills and self-conscious emotions, individuals' executive functioning could be substantially improved. Thus, the current research aims to illustrate the common neuropsychological background of learning and self-development. Furthermore, problem-solving skills have a major role in one's everyday life and their significance led to their inclusion in educational and therapeutic settings as a higher-order mental ability for learning and self-improvement purposes [50, 51, 52].

2 Cognitive and Metacognitive Executive Functions

Fischer et al. [3] presented the basis of a consistent training and assessment model encompassing Knowledge, Skills, Abilities and Other components (KSAO) regarding the Complex Problem Solving (CPS) competency. Problem solving is necessary for dealing effectively with complex non-routine situations in different domains, thus its requirements in knowledge, skills and abilities are innately dynamic and interrelated. By further exploring the KSAO model in a range of complex problem situations, an innovative methodology for training and assessing the Complex Problem Solving competency shall rise. More specifically, it might be more realistic to investigate a specific set of KSAO components, such as working memory, reasoning ability and intelligence, corresponding to a specific complex problem solving field. It is noteworthy mentioning that several moderating variables, such as problem features and additional factors, such as self-regulation interfere with predicting humans' problem solving performance. Furthermore, when a person solves a problem, by no means, is this indicative of that person's ability to solve another heterogeneous problem.

Rhodes et al. [4] investigated both the direct and indirect relation between executive functions and individuals' memory accuracy in terms of the latter's capacity to recall and monitor correct information. As executive functions decline with age, older adults exhibit low performance both in measures of their memory accuracy and memory monitoring. More specifically, older adults' ability to encode and retrieve information as well as their ability to monitor their feeling-of-knowing judgments diminishes, respectively. Notwithstanding, between executive functions and memory monitoring lays the quality of information available in one's memory. In the current study, there were two recall stages, either the forced recall or the free recall stage. In the forced recall stage participants had to provide as many correct responses as possible and in the free recall stage participants had to control the accuracy of their responses through calling the probability of being correct while setting a response

criterion. If the probability of being correct exceeds or is equal to the response criterion, an answer is volunteered; otherwise the response is withheld. Control processes influence accuracy by determining whether a response is volunteered or withheld. Therefore, the free recall stage encompasses three criterions in total; Monitoring effectiveness, control sensitivity and the respondents' incentive towards their accuracy estimation. Speed of processing and working memory was separately measured. The measures deployed in the study were: The Digit-Symbol Substitution Task, the Number Comparison Task and the Trail Making Test, the computerized version of the WCST, the Controlled Oral Word Association test and the Working Memory OSPAN task. The findings verified that memory accuracy, quantity of correct items retrieved and executive function were found to be directly related to age. Executive functions affected memory accuracy directly through their contribution to the quantity of correct responses available at the forced recall stage and indirectly through the monitoring of deceptive items at the free recall stage. However, memory monitoring partially mediated the quantity of the correct responses at the free recall stage for deceptive items, but not for control items. Overall, participants' accuracy of retrieved responses and memory monitoring can predict their memory accuracy. Furthermore, the relation between the specific components of executive functions in their full range and memory accuracy measures as well as the possible interplay between retrieval and monitoring processes are yet to be found.

Carden et al.[5] unraveled the role of visualization and working memory in mathematical problem solving performance. Visualization is a strategy in which individuals form a mental image depicting visual or spatial information in a more condensed and flexible manner so as to retain and connect data. The relation between visual-spatial skills and mathematics, including complex problem solving has been certified. The spatial ability and especially, the type of imagery used by individuals, is a significant factor for solving practical problems successfully. In addition, working memory capacity underlies retention and manipulation of information in individuals and it has consistently proven to be an efficient predictor of children's reading skills and mathematical ability. Therefore, visualization strategies and thus one's spatial abilities can mediate individual's working memory performance as he or she seeks for cognitive support when facing novel or complex problem solving situations.

Passolunghi et al.[6] examined the relation between arithmetic problem solving and working memory as well as the relation between arithmetic problem solving and short-term memory. In both cases, the underlying mechanism in the performance of the working memory was expected to be the inhibition of irrelevant information. Therefore, intrusion errors during recall in seven working memory and short-term memory tasks could be linked to the participants' word problem performance and/or to the inherent operation of the working memory, itself. The research was grounded in testing two groups; good problem solvers and poor problem solvers in the Listening span task, the Animal dual task, the Listening span completion task, the Counting span task and the Short-term memory tasks. There seems to be a generalized working memory deficit in poor problem solvers, regardless of verbal or numerical content and regardless of the task difficulty. Furthermore, when the two groups were controlled for their reading comprehension, no significant difference came up. However, the

poor problem solvers performed worse when the two groups were matched on their verbal intelligence. Thus, both the working memory system and arithmetic problem solving skills as well as one's working memory capacity and inhibition mechanisms seem to be more closely related. Overall, poor problem solvers were found less able to maintain, process or suppress irrelevant information of any kind, verbal and numerical, in their working memory. Metacognition could counterbalance this lack of flexibility in poor problem solvers performance through training their capacity to swift their selective attention to the appropriate strategies for encoding, accessing and inhibiting information from working and long-term memory.

Zheng et al.[7] compared mathematical word problem solving accuracy to elementary school children's working memory components through measuring their problem solving accuracy, problem solving processes, central executive component of working memory, reading and math calculation. Children between 6 and 12 grow faster on their executive ability, although their reading skills, arithmetic proficiency and fluency as well as their acquaintance with word problem solving processes may mediate the relationship between working memory components and problem solving accuracy. Tasks were divided into criterion, predictor and mediator variables. Criterion variables included mental solution of oral word problems. Predictor variables measured the phonological loop, the visual-spatial sketchpad and the central executive system. Mediators were considered measures of arithmetic calculation, reading and knowledge of word problem solving processes. As expected, chronological age was positively related to children's working memory performance as a whole. The tripartite working memory model by Baddeley with each component of working memory contributing unique variance to problem solving accuracy was confirmed in the present study as well. The phonological loop and the visual-spatial sketchpad influenced children's word problem solving accuracy and more specifically, the visual-spatial sketchpad, contributed unique variance to the problem solving accuracy. The central executive component had a prominent role in arithmetic word problem solving due to the controlled attention needed for inhibiting irrelevant information while accessing, updating and integrating information originating from long-term memory. Studies showing a weak correlation between working memory and problem solving were due to children's from 8 to 11 years old overlap between their phonological loop and working memory on several academic measures. As for the word problem solving accuracy, the phonological loop and the central executive were most influenced by academic mediator variables, such as reading and calculation proficiency.

Davidson et al.[8] made a comparative study on children, adolescents and adults' cognitive control skills and executive functions by measuring the interrelations and developmental progressions of their working memory, inhibitory control and task switching skills. Participants were assessed through a battery of 4 related tests for about 30 min in total. The first test was a classic Simon task, where the stimuli were presented randomly on the left or right of the screen over the block of 20 trials. In the second test, a single large arrow pointed straight down and participants had to respond on the same side as the arrow in a randomized mixed block of 20 congruent and incongruent trials at the left or right of the computer screen. In the Dots test, a large

dot was presented either at the left or right on each trial. The two types of dots used were either striped or solid, which indicated that when participants saw the striped dot they would have to make a response towards the same side, whereas when they saw the solid dot they would have to respond on the side opposite the dot. An initial block of 20 congruent trials was combined with a block of 20 incongruent trials as well as a block of 20 randomly intermixed trials. In the last test, each stimulus, an abstract shape, was presented in the center of the rectangle. For each stimulus participants were taught a rule and there were two conditions involving two- or six- abstract shapes. They first completed 2 blocks of 20 trials of the two-shape condition accompanied by 2 blocks of 20 trials for the six-shape condition. The dependent measures were accuracy of responses, speed/reaction time (RT) and percentage of anticipatory responses (AR). The results verified researchers' hypothesis that the cost of exercising inhibition to respond faster and more accurately on spatially incompatible trials (the Simon effect) decreased from 6 years of age onward. In regard to the integration of arbitrary rules related to the stimulus of each trial with the location of the stimulus, the spatial incompatibility effect decreased significantly from age 6 onward in accuracy, but only on the Arrows test. On the whole, participants' performance was slower and less accurate on switch than non-switch trials in both the Arrows task and the Dots-Mixed condition. However, the response time did not change between children of 6-13 years and adults on both arrows and Dots-Mixed condition due to the univalent stimuli employed in a task or rule. Furthermore, accuracy and impulsivity differences between the Dots-Incongruent and Dots-Congruent conditions decreased over age. Notwithstanding, on both the Arrows test and the Dots-Mixed condition adults and older children showed greater speed response cost for switching to the Congruent rule. Furthermore, adults' response time decreased when both the rule and response-site switched. However, the youngest children of 4-8 years performed better in accuracy and reaction time on switch trials where the response-site remained the same. Therefore, cognitive flexibility in an intermixed, task-switching context, characterized by the "all or none" principle where participants inhibit a dominant response all the time, was evident in participants with mature cognitive system, after 13 years of age. The last finding indicates that adult participants adjusted their speed to preserve accuracy on the more difficult trials. On the contrary, young children were often too impulsive to take the time they needed at the cost of accuracy. Moreover, adults seemed to be able to reset their default response between the two conditions of the Mixed block in order to exercise inhibition in a steady state. Furthermore, the study aimed to delineate the interactions among the basic executive processes, such as inhibitory control, memory and task switching. As far as the inhibitory control is concerned, the ability to inhibit attention to distractors or the ability to inhibit a strong behavioral inclination is tied to a person's cognitive flexibility. Consequently, selective and sustained attention is critical for adaptability and creativity in the way people hold and manipulate information. When the tasks were similar in difficulty, participants' speed on working memory and inhibition were highly correlated, whereas their accuracy on working memory and inhibition was respectably correlated.

Anderson[9] conceptualizes executive function as an integrated supervisory or control system, made up of multiple process-related systems. More specifically, attentional control processes include the capacity to selectively attend to specific stimuli and inhibit prepotent responses as well as the ability to focus attention for a prolonged period. In advance, individuals' acquiring attentional control involves the regulation and monitoring of actions in order for them to complete tasks, avoid procedural mistakes and respond appropriately. Furthermore, information processing can be evaluated by the speed, quantity and quality of output. Cognitive flexibility, including the working memory capacity, refers to the ability to shift between response sets, learn from mistakes, devise alternative strategies, divide attention and process multiple sources of information concurrently. Finally, goal setting lays on individuals' ability to develop new initiatives and concepts while planning actions to approach tasks in an efficient and strategic manner. Effective assessment of children's executive function is quite challenging due to the need for capturing quantitative factors as well as cognitive-related processes and behavioral elements. Moreover, individuals' executive control reaches its maturity when the respective cognitive processes are fully established around mid-adolescence or early adulthood. Therefore, longitudinal studies will be required so as to verify any conceptualization concerning executive function development.

Keil et al.[10] describes executive processes as a prerequisite function for individuals' adequate response to novel and complex environmental demands. The former consist of several cognitive processes, such as self-monitoring, self-awareness and self-regulating, inhibiting irrelevant stimuli, shifting between concepts or actions, generation and application of strategies, temporal integration of information as well as recruiting or integrating multimodal inputs from throughout the brain. More specifically, researchers compiled an annotation of neuropsychological tests for the purpose of identifying the abilities that underlie executive functions and therefore discriminate cognitively impaired patients. Neuropsychological experiments should encompass multiple measures or administration of control tasks in addition to executive-level tasks so as to discern the executive functions from other contributing factors, such as basic or focal processes. Overall, control tasks should tap visuospatial, attentional or other processes likely to be involved in respective executive function tests. Moreover, the cognitive processes addressing participants' planning, scheduling, strategy use and rule adherence compose the first set of executive function tests. In addition, executive control processes, such as generating word or designs without repetition and complying with environmental constraints, are subject to monitoring skills and can be measured by fluency and generation tests. The third category of tests is centered on sustaining or/and shifting attention and suppression of habitual responses through self-regulating one's behavior. Finally, tests of concept formation and abstract reasoning, requiring continuous monitoring and modulation of output, tap another domain of executive functions. As many of the aforementioned tests deploy linguistic processes or language, the relation between executive functions and verbal intelligence via internal speech or verbal mediation in language-disordered population, should be clarified.

Strobach et al.[11] showed that experienced video gamers acquire optimized and speeded executive control processes as they coordinated two different tasks either simultaneously in dual-task situations with novel stimuli or stimulus-response mappings or sequentially in task switching tests. The researchers made two experiments in order to investigate video game trainees' improved executive control skills in an attempt to select and execute multiple responses. The first experiment taken place, involved a dual-task test consisting of a single-task situation and a series of dual-task block trials with the simultaneous presentation of auditory and visual stimuli. The second one, constituted a task-switching test with single and mixed–task blocks, wherein predictive switches occurred between task-switch trials and repeat trials. Both tests were performed before and after video game practice. A scatter plot of the Brinley-plot type demonstrated action video gamers' superior executive control skills in complex situations calling for an effective regulation of the switch between conflicting stimuli in intermixed task settings. It seems that executive control skills can be improved, thus become traceable when a person coordinates different tasks involving simultaneous or sequential, but certainly rapid switches between them.

Pureza et al. [12] present the relationship between executive functions, such as the central executive of working memory, inhibition, cognitive flexibility and self-monitoring in late childhood. The instruments deployed were the Unconstrained, Phonemic and Semantic Verbal Fluency subtests of the Montreal Battery of Evaluation of Communication, the Random-Number Generation task, the Bells Test, the n-back Test and the Hayling Test. The results suggest a relationship between inhibitory control, cognitive flexibility, processing speed as well as the central executive of working memory. More specifically, a strong association was brought into light between language alternation as an aspect of cognitive flexibility and inhibitory control as the ability to inhibit responses unrelated to the context. Likewise, selective attention and processing speed in verbal fluency were also related. On the one hand, attention, inhibition and verbal-semantic linguistic processing and on the other hand, focused attention, inhibition, verbal processing speed and self-monitoring were found to be linked. Furthermore, inhibition and cognitive flexibility of semantic verbal fluency were related to the central executive component of working memory. Regression analysis on larger samples could verify and expend current findings.

Rudkin et al.[13] inquired into the relation between the visual-spatial and central executive components of working memory through a triplet of dual-task coordination experiments. The central executive is responsible for complex functions, such as comprehension, reasoning, strategic cognitive control and dual-task coordination. Both visual and spatial working memory tasks, the Matrix Patterns and the Corsi Blocks respectively, were used as a means for discriminating the function of visual and spatial working memory subcomponents. The dynamic role of the spatial component is apparent as it records and encodes information about movements and sequences of movements as well as it entails one's inner ability to monitor and control his spatial attention. Thus, there seems to be an interrelation between one's executive functioning and his visual-spatial processes, which is worthy to be looked into. In the first experiment, central executive processes, such as information updating, attention shifting and inhibiting inappropriate information were more closely related to the

spatial component than the visual component in a dual-task condition. In this case, both the Matrix Patterns task and the Corsi Blocks task were combined concurrently with an oral random generation task. Participants' performance in the spatial task decreased much more than their performance in the visual task, indicating the former's tapping of executive processes, although there was no significant difference in random generation performance between the two dual-task conditions. In the second experiment, researchers investigated the effect of a dual-task condition experiment combining the concurrent presentation of an oral random generation task and a visual-spatial task, either with sequential or simultaneous stimuli. The results of the second experiment verified the assumption that the recall of both item and order information in a serial sequential presentation taps of central executive functioning more than in simultaneous visual-spatial tasks. Finally, the third experiment controlled for the interference of short-memory in the random generation task, thereby minimizing its influence on the measurement of executive functioning. The two previous visual-spatial tasks were concurrently combined with either random- and fixed-interval auditory tone repetition tasks. More specifically, the fixed-interval tone task was expected to load the executive to a lesser extent than the random-interval task. However, both tone tasks interfered with the sequential presentation task only and the disruption caused by the two tone tasks was not significantly different. Overall, a serial-sequential visual-spatial task taps of executive processes to a greater extent than simultaneous item information presentation tasks. This is because sequential presentation may lead to a significant increase in one's demand of strategic monitoring and control over the encoding and rehearsal of the mental path configurations from the movement patterns of the stimuli. The question remains which part of the sequential task, encoding, maintenance or retrieval, places greater executive load.

Yates et al.[14] made a correlational study between executive processes and other functions, such as working memory, the executive attention construct, attention and prospective memory. In this study, it is insinuated that shifting, inhibition and updating are three independent, but interrelated subprocesses compiling one's executive function. Shifting corresponds to attention switching or task switching. Inhibition is the intentional and controlled suppression of dominant, automatic and prepotent responses. Updating lays on renewing and monitoring the working memory representations. Previous studies considered executive functions as a fraction of goal directed behavior, attention control, temporal organization and planning. In the current study, the Wisconsin Card Sorting Test was implemented as a means for measuring participants' cognitive flexibility and problem solving skills. In addition, the Brazilian Brief Neuropsychological Assessment NEUPSILIN measured participants' time and spatial orientation, sustained auditory attention, visual perception, memory, arithmetic abilities, language skills, motor abilities and two subcomponents of executive functions, such as solving simple problems and verbal phonemic-spelling fluency. The study aimed at relating one's performance in the WSCT to one's performance in the cognitive tasks encompassed in the NEUPSILIN. The results verify the existence of the executive attention construct that is the ability to keep an objective in active state during the task and the ability to overcome

interference, particularly in a conflicting situation. Sustained attention, prospective memory and verbal fluency were moderately correlated in tests as well as executive functions correlated with episodic-semantic memory and oral and written language. Furthermore, one's executive function was related to one's working memory capacity. WCST entails both visual and oral language stimuli for the tapping of abstraction, insight formation and mental flexibility, thus depicting the multi-modality of the measure. Nevertheless, more implicit language recognition demands in the tasks would deliver greater language inferential processing associations by virtue of the close relation between visual-spatial information and executive functioning or attentional control.

Cinan et al.[15] shed light on the interplay between the central executive and the phonological loop through manipulating the Wisconsin Card Sorting Test. The executive systems responsible for the different types of executive functions involve the phonological loop and the visuospatial sketchpad. In the current study, a dual-task design was included, with the secondary tasks either taxing the phonological loop or the central executive so as to investigate on the specific role of the phonological loop while addressing the novel types of the WCST. In all three versions, the WCST-4 stimuli, the WCST-12-stimuli and the WCST-12-stimuli-box, participants were given the exact sorting criterion in order to avoid loading on the phonological memory. However, in the WCST-4 stimuli the same four stimulus card materials were used as in the original WCST. On the contrary, the WCST-12-stimuli and the WCST-12-stimuli-box encompassed unidimensional stimulus cards. More specifically, in the WCST-12-stimuli-box condition, boxes were used to conceal the response cards previously sorted. In the first two dual-task experiments, the WCST-4 stimuli were performed simultaneously with either an articulatory suppression task or the letter generation task accompanied by a control, single-task condition. The articulatory suppression task taps the phonological loop and the letter generation task taps the central executive. The second two dual-task experiments included the concurrent use of the WCST-12-stimuli with the letter generation task as well as the use of the WCST-12-stimuli-box with the letter generation task. The study verified that the phonological secondary task had no effect on the performance of the simple version of the WCST, aimed to relish participants of any phonological memory load. Therefore, the response inhibition processes measured primarily in the simple new version of the WCST were found to be mediated by the executive secondary task, whereas participants' inhibitory control was found not to be mediated by the simultaneous use of their phonological loop. Moreover, the visual features taxing participants' inhibitory control in the simplest type of the WCST as well as participants' concurrent use of the executive secondary task affected their overall executive function. Researchers place their future interest on the separate role of allocating attention in the central executive, mainly through adopting a version of the WCST that entails updating and maintaining the information about the sorting criterion of 12 stimulus cards, mixed and placed in a random way. The response cards could be shown one by one by the researchers and the ones shown could be hidden. The participants should not be given the sorting criterion. Thus, the aforementioned experiment could offer the means for a thorough investigation on the role of attention

and visual-spatial working memory in individuals' executive function as well on the possible relation between attention and visual-spatial working memory.

Nouchi et al.[16] made an intervention study on the effects of a Learning Therapy encompassing reading aloud and solving simple arithmetic calculations in elderly people on a range of cognitive processes, such as processing speed, verbal and facial episodic memory, short-term memory, working memory, focus attention, reading ability and inhibition and shifting as executive functions. The cognitive intervention had duration of 23 weeks, during which the difficulty level of training tasks and workloads did not change. Before and after the intervention period, the following cognitive measures were implemented: the Stroop Test and the Verbal fluency task measuring executive functions, the Digit cancellation task measuring attention, the Logical memory as well as the First and second names test measuring Episodic memory, the Digit span forward measuring Short-term memory, the Digit span backward measuring Working memory, the Japanese reading test measuring Reading ability and finally, the Digit symbol coding and the Symbol Search test measuring Processing speed. The cognitive intervention group exhibited improved inhibition, verbal episodic memory, focus attention and processing speed compared to the waiting list control group. The aforementioned relation was investigated by virtue of the overlapping cognitive processing underlying the learning therapy and the cognitive measures. For instance, comprehending and reading a sentence relies on semantic and verbal episodic memory as well as on focus attention. Processing speed and inhibition affects arithmetic calculation problem tasks. However, shifting and facial episodic memory measures remained constant as their enfolded cognitive processes, such as clustering, switching, face recognition and association were intact by the learning therapy. Therefore, executive functions and episodic memory as well as working memory are constructs that necessitate multiple measures for investigating individuals' cognitive functions. In addition, future studies should entail intensive adaptive training throughout the intervention period including other types of cognitive training, such as working memory training.

Fried et al.[17] made a comparative study concerning the effects of working memory deficits on children with and without ADHD. Working memory deficits have already been linked to academic deficits beyond ADHD. It is worth mentioning that one study showed the negative impact of impaired working memory on non-ADHD individuals' focusing attention, inhibition of irrelevant stimuli, recognition of priority patterns, ability to recognize hierarchies and the meaning of stimuli, establishing an intention as well as recognizing and selecting the goals that are best suited to solving a problem. In this study, the scope of impact of deficits in working memory was evaluated through stratifying children's with and without ADHD working memory deficits. The psychiatric assessment was succeeded by the intellectual functioning assessment encompassing the Vocabulary and Block Design, subtests of the Wechsler Intelligence Scale for Children-Revised as well as the Freedom from Distractibility (FFD) Factor from the WISC-R. The first tests measured participants' IQ and the second assessed the working memory. Reading and arithmetic achievement were measured with subtests of the Wide Range Achievement Test-Revised. The findings verified that working memory deficits in ADHD children significantly increased the

risk for grade retention, placement in special classes and lower academic achievement, both in reading and math. More specifically, children with ADHD and comorbid working memory deficits are much more susceptible to cognitive and academic deficits in contrast to children with ADHD and no deficits in working memory. As working memory deficits and ADHD represent separate, comorbid conditions, appropriate educational intervention could assist children face up to their respective adversities. In addition, children with ADHD and with comorbid working memory deficits may comprise an innovative field of study in neuroscience. Research on the educational and cognitive outcomes in the general population originating from working memory deficits is also an ample field of study.

Francesco et al.[18] reviewed on the executive function deficits in Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD). Research on the executive function deficit directly associated with the aforementioned groups lays on the latter's shared genetic and neurobiological underpinnings, leading to a disturbance at the level of the executive functions. Moreover, the co-occurrence of ASD and ADHD could inaugurate a combined phenotype, reflecting an additive comorbidity, thus augmenting enhanced treatment options. Executive functions, such as planning, spatial and verbal working memory, response inhibition and vigilance have been linked to ADHD children/adolescents. Moreover, an ADHD subtype, the ADHD-I has been related to sluggish, disorganized behavior. Children with ADHD also have deficits in sustained attention and visual memory. Likewise, constant impairments in cognitive flexibility, planning and working memory have been found in individuals with high-functioning autism. In addition, children with autism have shown more deficits in shifting attention, sustained or selective attention and response inhibition. Furthermore, a clinical combined phenotype, ASD+ADHD, was attempted to be investigated separately regarding the level of the following executive functions: inhibition, working memory, flexibility, attention, planning, monitoring, preparatory processing, fluency and concept formation. Attention was found to be dysfunctional in all clinical groups (ASD, ADHD and ASD+ADHD). The ADHD children had a deficit in the manipulation of sustained and divided attention compared to healthy children, whereas children with ASD+ADHD performed worse in divided attention and alertness tasks compared to their healthy counterparts. In contrast, both ASD and ASD+ADHD groups were found to be lacking in cognitive flexibility and planning. The ASD was particularly related to cognitive flexibility deficit and the ASD+ADHD group was found to be impaired in duration concerning both flexibility and planning tests. ADHD and ASD+ADHD groups were also lacking in response inhibition. Consequently, cognitive training in executive functions may change the underlying neural mechanisms to improve the above groups' real-world function.

Mertes et al.[19] investigated the effects of spatially and temporally irrelevant information on the processing of subsequent information. Relevant information is maintained in visual working memory and its representations facilitate the adaptability of the human behavior. Notwithstanding, visual attention is captured by irrelevant objects in the visual field. Thus, these automatic, involuntary shifts of attention occur due to distracting salient stimuli or stimuli that match the representations held in visual working memory. As a result, suppression mechanisms

are activated, the attentional control sets, to re-orientate and reallocate one's attention to the sought-after objects. Moreover, it has been found that individuals' responses at spatial cueing tasks are faster when the target and the preceding cue shared the same location. Attention was already drawn to the location of the cue, thereby reinforcing the processing of the object, subsequently presented at that location. In the present study, an irrelevant color cue that was either contingent (color search) or non-contingent (shape search) on attentional control sets was presented, prior to a target array with different stimulus-onset asynchronies (SOA). More specifically, cue displays containing a lateralized color singleton were presented prior to the target display. Participants were instructed to ignore the task-irrelevant cue display as the cue position did not allow for predicting the target position. In one condition, both cue and target singletons were defined by color (contingent condition). In the non-contingent condition, color singleton cue and target singleton did not share features in order to facilitate the inhibition of the color singleton cue. Researchers measured event-related potentials (ERPs) evoked by the cue display. The findings of the study sum up to two independent filtering stages regarding the passage of information into working memory. First, an early selection process represented by an N2 posterior contralateral (N2pc) to the singleton cue and a component labeled distractor positivity (Pd-early), enables the active re-orienting of the attentional focus in the search array when irrelevant information matches working memory templates. Second, there is a more conservative filtering stage determining visuospatial working memory access, associated with Contralateral delay activity (CDA) and distractor positivity (Pd-late) component, which encompasses the active maintenance of working memory representations surviving after the first inhibition of the cued location as well as the final inhibition of the false representations as soon as the relevant information is obtained. At that point individuals are able to proceed with the rapid perception of the target. Therefore, attentional processes seem to be strongly linked to cognitive control mechanisms, such as the distractor positivity (Pd) component that assists people to prioritize their targets. The distractor positivity (Pd) component has been found to be subjected to exterior incentives, such as rewards. Furthermore, individuals' attentional mechanisms through the manipulation of their distractor positivity (Pd) component are adaptable and susceptible to motivation.

3 Emotional / Motivational Executive Function

Channon [20] describes brain-injured individuals' effect on their problem solving skills. More specifically, executive dysfunction in cognitively impaired individuals lays on their difficulty to shift between novel tasks due to their inability to access and manipulate prior knowledge, to appreciate the problem situation in working memory, to generate appropriate strategies, to inhibit inappropriate responses as well as to monitor and judge the effectiveness of problem solutions. Therefore, focus on individuals' actual behavior entails both their real-life-type problems and their actual problem-solving performance. Adults with focal lesions or other neurodevelopmental disorders, such as the Asperger's syndrome, Tourette's syndrome as well as healthy

versus younger people were tested on their ability to generate as many possible ways of solving an awkward problem situation as they could. Each solution was further coded and rated in terms of the examinee's appreciation of the pertinent aspects of the problem, the social appropriateness of his solutions and the effectiveness of his solution from a practical viewpoint. After the solution generation phase, participants were asked to give their preferred final solution for the problem, both from the perspective of the main character and for themselves. Patients with left anterior lesions and the two neurodevelopmental groups showed impaired problem-solving, both in generating a range of high quality potential problem solutions as well as in selecting appropriate preferred solutions. In advance, the aforementioned groups' performances on clinical executive tests, such as the Wisconsin card sorting test, the Rule shift test, the Hayling test, the Letter fluency Test and the six Elements test were rather inconclusive as to the detection of differences between the groups. Nevertheless, there were positive correlations between the clinical executive tasks and the number of solutions generated as well as the average total final quality of solutions provided by the participants. Focusing and sustaining attention, generating and using an appropriate strategy, maintaining information in working memory, shifting between ideas and inhibiting inappropriate ideas is executive processes needed in everyday settings. Thus, weak performances on the average number of solutions or on selecting appropriate problem solutions result from deficiencies in abstract executive skills, such as encoding of successful methods of approaching problem situations and discarding or appropriate labeling of less successful methods were linked to a positive final outcome. In short, both quality of the available knowledge itself in combination with the identification, accessibility and activation of the necessary material in working memory form an efficient strategic memory operation. Nevertheless, life experience seems to be equally important in ill-defined problems as healthy older people showed preservation of performance on the complex problem solving task but performed worse on several of the clinical executive measures compared to the healthy young group. On the other hand, the Asperger syndrome group had a difficulty in selecting solutions that were socially appropriate, probably due to a deprived social life and thus, these people lacked in quality and quantity of social knowledge structure. Moreover, even though there is some evidence for the independence of social cognition and non-social executive abilities, the exact relation between executive functions and theory of mind skills seems to be rather vague.

Beck et al. [21] attempted to link middle-childhood children's personal characteristics to their innovative problem solving capacity. At first, researchers compared children's performance on tool-innovation tasks with measures of children's fluency in divergent thinking. In the Circles task, children drew as many different pictures as they could on a circle template, in the Object uses task, they had to suggest multiple uses for objects and in the Hook-innovation task the experimenter showed the child a bucket with a sticker at the bottom of the tall transparent tube and prompted the child to get the sticker. Notwithstanding, none of these measures of divergent thinking was a significant predictor of children's innovation success. Furthermore, children's fundamental executive functions, their inhibitory control,

working memory and attentional flexibility were measured accompanied by the tool-innovation task; the Six Parts Test, a measure of ill structured problem solving. Additionally, children completed the British Picture Vocabulary Scale-II, a supplementary measure of general intelligence. The findings showed that there was a relationship between innovation and receptive vocabulary but no evidence between executive function and children's innovation success. The inconclusive results insinuate that it may be another cognitive process related to innovation, such as analogical reasoning as well as a personality trait and/or positive, social learning experiences of successful innovation that comprise an innovative child.

Petrovic et al. [22] presented an integrated model of mechanistically related processes, either emotional or non-emotional, tied to the dysfunctional top-down regulation of information processing in ADHD and emotional instability disorders. Top-down regulation refers to the reciprocal interaction of information between multiple regions in large-scale, emotional and non-emotional networks with hierarchical perception-action organization. Thus, the highest level of emotional and non-emotional processes performs the more complex and temporally dispersed information. Moreover, top-down control of the emotional and the non-emotional systems vary in their efficiency among the general population. In addition, ADHD patients have been associated with poor non-emotional top-down control and individuals with emotional instability disorders have been associated with poor emotional top-down control. Therefore, patients' with ADHD would show a dysregulation in the non-emotional system and normal emotional regulation, whereas individuals with emotional instability disorders would show a dysregulation in the emotional system and normal non-emotional regulation. Comorbid states may encompass poor capacity for both non-emotional and emotional processing. However, the aforementioned dysregulation shares common grounds on account of an underlying neuromodulatory mechanism, the dopamine system, which interacts with both emotional and non-emotional networks. Its proper treatment would affect the whole regulatory brain network, processing either emotional or non-emotional types of information.

Jiang et al.[23] explored emotional regulation and executive functions in the Oppositional Defiant Disorder (ODD) and in ADHD children. Additionally, the relationship between emotional regulation and executive functions were intrinsically investigated. In the dual-pathway model of executive functions, attention, working memory, planning and response inhibition pertain to cold executive functions in comparison with the hot executive functions embracing one's emotional and motivational regulation. Although ADHD children have been related to most executive function deficits, both cold and hot, ODD children have been connected mainly to deficits in individuals' visual working memory and response suppression/inhibition. The present study is particularly interested in the relation of ODD and ADHD children with emotional regulation as part of executive functioning, subjected to motivations and emotions. The Adolescent Daily Emotional Regulation Questionnaire (ADERQ), the Wisconsin Card Sorting Test (WCST), the Wechsler Intelligence Scale for Chinese children (WISC-IV), the Stroop color-word association test and the Cambridge Neuropsychological Test Automated Battery (CANTAB)

were the research tools deployed. The findings of the study verified that ODD children face deficits in emotion regulation processes, albeit their exact behavioral characteristics as well as their whole executive functioning profile and the role of the comorbidity with the ADHD syndrome in their emotion dysregulation remains unclear. Notwithstanding, the ability to regulate emotions is an important part of an individual's executive functions. In this case, ODD children were prone to greater number of perseverative errors due to their lack in self-reflection, self-control and self-regulation of negative emotions combined with deficits in working memory and planning capabilities. On the whole, response inhibition incapability, planning dysfunction and emotion dysregulation were important risk factors for ODD children.

Van Stralen[24] made a review study on the relation between children's emotional dysregulation and attention-deficit/hyperactivity disorder. Emotional dysregulation stands for one's reactive or motivational control problems leading to hyperactivity-impulsivity symptoms due to inappropriate internalized (sadness, depression) or externalized (anger, aggressiveness) emotional responses. More specifically, the emotional dysregulation in ADHD refers to individuals' lack in a whole set of cognitive and meta-cognitive skills, such as attention, self-control, self-regulation and self-monitoring. Furthermore, emotional impulsiveness as well as deficient self-regulation of affections-motivation-arousal, internalization of speech and reconstitution in the ADHD syndrome co-occurs with other executive functions, such as inhibition and working memory. Latter research illustrated that ADHD individuals' behavioral dysregulation and difficulties in metacognition are interconnected. Thus, their emotional dysregulation and deficits in executive functions can be interdependent and all contribute independently to distinguishing between children with ADHD and controls. Further research on the field of emotional dysregulation in ADHD individuals could offer a crystallized definition of the construct as well as a comprehensive methodology for building innovative training and assessment tools.

4 Executive Function Abilities and Problem Solving

Nguyen et al. [25] made an intervention study to enhance older adults' complex decision-making abilities through a problem-solving therapy modality. It has been shown that some older adults may experience a greater decline in non-memory-related cognitive functioning, such as problem-solving and mental flexibility, contributing to weaknesses in their decision-making abilities [26]. The findings from the current study demonstrated that a four-session (approximately 2 weeks) problem-solving therapy requiring abstract problem-solving with inductive reasoning and flexible adjustment of responses based on feedback can reinforce aspects of executive functioning (that may have declined as a part of healthy aging), thereby enhancing decision-making abilities. Such executive skills encompass emotional regulation, behavioral initiation, planning, organization, cognitive flexibility and problem-solving [27]. In conclusion, this intervention promoted older adults' self-efficacy and ability towards resolving practical everyday challenges.

Problem solving therapy (PST) relies on a learning model that assists older adults with major depression and executive dysfunction to identify problems central to their lives, select solutions and make concrete plans for problem resolution. This therapy has been found effective for improving patients' self-care, household and work activities, getting around, understanding and communicating, getting along with others as well as participating in social activities [28].

Kurowski et al.[29] described their randomized clinical trial (RCT) design to examine the comparative effectiveness of three versions of F-PST (family problem-solving therapy) in improving/ameliorating patient- and caregiver-reported behavioral outcomes regarding traumatic brain injury (TBI). Face-to-face; online and self-directed and therapist-supported online modes of treatment are going to be tested for their effectiveness in patient outcomes. Youth with TBI and their families in all three treatment groups will receive 10 sequential sessions providing training in staying positive/cognitive reframing, problem-solving, communication, and self-regulation/anger management. Parents and youth with TBI will complete the Behavior Rating Inventory of Executive Function (BRIEF), a rating of the child's executive functioning abilities.

Zelazo et al. [30] aimed to improve preschool children's executive function skills, such as cognitive flexibility, working memory and inhibitory control through goal-directed problem solving. As it is already known executive function skills can be fostered through reflection training as individuals acknowledge and are able to manipulate their cognition and emotions. The 6-week intervention comprising both mindfulness and reflection training was found to improve preschool children's executive function skills in the long run, which indicates a transfer effect of the trained executive skills on future problem-solving situations and assessments [31].

Problem-centered, collaborative environments offer personal challenges and, over the long run, help students gain higher-order executive processes. Effective instructing is a dynamic, interactive process, akin to problem-solving [32]. Executive functioning is the most important process for adaptive, planful learning and thinking. Initially, the primary executive process is to analyze the task at hand and to select an appropriate strategy; during the course of learning, its role shifts to strategy monitoring and revision [33]. Interestingly, in younger children, inhibition was found to be the strongest predictor of problem solving, whereas working memory contributed more strongly in older children's problem solving capacity [34]. In another study, cool Executive Functioning (EF) predicted math achievement, learning-related classroom behaviors and observed engagement in kindergarten [35].

In addition, research suggests a vital role for executive function in children's social–emotional development. However, executive function is rarely considered in models of intervention programs that attempt to promote social–emotional competence [36]. Children who demonstrated better inhibitory control were more likely to be rated higher on social skills and lower in internalizing behaviors. Findings suggest that early identification of inhibitory control difficulties may be beneficial for targeting children at risk for maladaptive outcomes. Moreover, executive function (EF) in 6 year old children predicted first-grade teachers' ratings of emotional symptoms, hyperactivity, and conduct/peer problems [37]. The contribution of

environmental experience to the development of inhibitory control skills suggests there are many opportunities to intervene during early childhood [38].

The neuropsychological symptoms seen in adults with ADHD may be explained by deficits in executive function, mainly composed of inhibition and metacognition. Deficits in inhibition of motor, verbal, cognitive, and emotional activities contribute to inattention in adults with ADHD. These deficits originate in metacognitive aspects of cognition, such as nonverbal working memory, verbal working memory, planning and problem-solving, as well as emotional self-regulation. Therefore, by enhancing metacognitive functions, inhibitory control could also be improved [39].

Furthermore, Goal Management Training is a metacognitive, tailor-made intervention for executive functioning deficits intended to promote a mindful approach to problem-solving by raising awareness of attentional lapses and reinstating cognitive control when behavior is mismatched to the ongoing goal hierarchy [40, 41, 42]. In addition, executive functions receive input from higher-level metacognitive processes, such as self-monitoring, self-assessment, values, motivations and beliefs about the ''self.". This active self-monitoring may facilitate the revision or updating of the individual's metacognitive beliefs, but also contributes to making decisions about the use of strategies, called self-control [43].

Therefore, disorders of planning and problem solving, such as Traumatic Brain Injury (TBI) can be treated through improving individuals' self-monitoring accuracy and thus, strategic decision-making [43]. In addition, the maturity of social problem-solving skills mediates the relationship between executive function and social outcome in paediatric traumatic brain injury (TBI) [44].

5 Results

The common ground of the aforementioned studies lays on the distinct, although interdependent, executive functions and their relation to individuals' everyday behavior and learning. Either intellectually-based processes or emotional/motivational-based executive processes, they are all necessary for every day, complex problem solving tasks [48]. Therefore, executive functions consist in cognitive, metacognitive and emotional constructs, especially individuals' sustained or selective attention, response inhibition and emotional regulation. In advance, executive functions are innately related to encoding, accessing, updating and self-monitoring of problem-solving strategies and solutions, such as those learned in science, maths and technology [49].

Moreover, it is hypothesized that attention and the cognitive control mechanism could have a positive effect on the metacognitive, regulatory mechanism behind the emotional system, as well. In any case, the attentional control mechanism was preliminary destined to improve infants' behavior. Therefore, an improvement in the attentional control mechanism could offer either an emotional boost or an adaptable behavior, possibly due to one's capacity to regulate his emotions.

By being able to self-regulate cognition and emotion in a systemic way, individuals could improve their actual problem solving performance and real-world function.

More specifically, several everyday decision-making issues require shifting between novel tasks, appreciating the problem situation according to the representations located in the working memory, generating appropriate problem-solving strategies, inhibiting inappropriate responses as well as monitoring and judging the effectiveness of problem solutions. Furthermore, emotional regulation as the counterpart of metacognitive executive functions influences individuals' social behavior, an intrinsic human need.

Attention skills were found to be related to inhibitory control so as to support individuals' cognitive flexibility; that is the ability to inhibit attention to distractors or the ability to inhibit a strong behavioral inclination. Thus, selective and sustained attention has a key role in the way people hold and manipulate information. Therefore, attentional control processes encompass the capacity to selectively attend to specific stimuli, inhibit prepotent responses as well as the ability to focus attention for a prolonged period and regulate/monitor one's actions.

In addition, according to Ardila[2], individuals' attentional control processes are primary (they emerge by the child's 1st year), include meta-cognitive control mechanisms and lead to improvements in the ability to inhibit overlearned behavior (inhibitory control of behavior). Furthermore, attention was found to be adaptable and subjected to affective states (motivation). Controlling emotions and the brain's reward systems are also intrinsically related processes [45]. Therefore, attentional control and emotional regulation have a common mediator; motivation. Overall, by improving executive functions and especially individuals' attentional control, their learning capacity and social adaptability is enhanced through their cognitive and emotional upgrade.

6 Conclusion

Executive functions are interweaved cognitive and metacognitive processes encompassing individuals' cognitive skills, values, beliefs as well as self-regulation abilities. Self-regulation regarding one's cognitive skills, such as attention, memory, inhibitory control, problem solving skills has proven to be related to one's emotional self-regulation. Thus, individuals facing emotional and/or executive shortcomings, such as older adults, individuals facing Traumatic Brain Injury (TBI), individuals with ADHD, Autism Spectrum Disorder as well as Oppositional Defiant Disorder and their comorbidities can be substantially assisted in their everyday problem solving through improving their overall self-regulation. Moreover, by training young children's self-regulation, their learning potential and conduct are improved as their cognitive/metacognitive and emotional processes are enhanced.

More specifically, metacognitive executive functions are complementary to each other as attention, self-monitoring, working memory capacity, inhibitory control and task switching are interrelated functions, affecting individuals' cognitive control mechanism. Even more, attention seems to have a supreme role among these core, metacognitive executive functions in the orchestration of information processing, thus creating cognitive flexible individuals. However, attentional processes develop early

in humans in order to address their need for adapting their behavior. In this sense, attentional control could improve individuals' emotional regulation throughout their growth, as well.

In essence, attentional control can facilitate individuals' whole spectrum of executive functioning, cognition and behavior. Interestingly, selective and sustained visual attention measured through a distractor positivity (Pd) component in a serial sequential presentation attentional control, were found to be susceptible to exterior incentives. Thus, attention processes are adaptable and liable to training [46, 47].

Consequently, future studies should look into the relation between attentional processes and one's ability to regulate his emotional/motivational executive functioning; One's emotional/motivational executive functioning is tied to the underlying cognitive control processes regarding his inner and social emotions. In that case, older adults, individuals facing Traumatic Brain Injury (TBI), individuals with ADHD, Autism Spectrum Disorder as well as Oppositional Defiant Disorder and their comorbidities, would be sufficiently assisted in their need to regulate their emotions or motivational control. Such an advanced research in the bidirectional relation between executive function and problem solving skills could develop a comprehensive methodology for training and assessing self-regulatory processes.

Moreover, the aforementioned research would offer tangible proof of the fact that metacognitive executive functions and emotional/motivational executive functions are interweaved in a holistic view of "self-consciousness". That is the interdependence of one's cognition/metacognition and his inner emotions or even further, the interdependence of one's cognition/metacognition and his social emotion (theory of mind).

7 References

[1] Ardila, A. (2016). Is self-consciousness equivalent to executive function? Psychology and Neuroscience, 1-6. https://doi.org/10.1007/978-3-319-50340-0_43

[2] Ardila, A. (2013). Development of Metacognitive and Emotional Executive Functions in Children. Applied Neuropsychology: Child, 1–6. https://doi.org/10.1080/21622965.2013.748388

[3] Fischer, A. and Neubert, J. C. (2015). The multiple faces of complex problems: A model of problem solving competency and its implications for training and assessment. Journal of dynamic decision making, 1(6): 1-13. https://doi.org/10.3991/ijep.v8i2.8228

[4] Rhodes, M. G. and Kelley, C. M. (2005). Executive processes, memory accuracy, and memory monitoring: An aging and individual difference analysis. Journal of Memory and Language, 52: 578-594. https://doi.org/10.1016/j.jml.2005.01.014

[5] Carden, J. and Cline, T. (2015). Problem solving in mathematics: the significance of visualization and related working memory". Educational Psychology in Practice, 31(3): 235-246. https://doi.org/10.1080/02667363.2015.1051660

[6] Passolunghi, C. M. (2001). Short-Term Memory, Working Memory, and Inhibitory Control in Children with Difficulties in Arithmetic Problem Solving. Journal of Experimental Child Psychology, 80: 44-57. https://doi.org/10.1006/jecp.2000.2626

[7] Zheng, X. Swanson, H. L. and Marcoulides, G. A. (2011). Working memory components as predictor of children's mathematical word problem solving. Journal of Experimental Child Psychology, 110: 481-498. https://doi.org/10.1016/j.jecp.2011.06.001
[8] Davidson, M. C. Amso, D. Anderson, L. C. and Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia, 44 (11): 2037-2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006
[9] Anderson, P. (2002). Assessment and Development of Executive Function (EF) during Childhood. Child Neuropsychology, 8(2): 71-82. https://doi.org/10.1076/chin.8.2.71.8724
[10] Keil, K. and Kaszniak, A. W. (2002). Examining executive function in individuals with brain injury: A review. Aphasiology, 16(3): 305-335. https://doi.org/10.1080/02687030143000654
[11] Strobach, T. Frensch, P. A. and Schubert, T. (2012). Video game practice optimizes executive control skills in dual-task and task switching situations. Acta Psychologica, 140: 13-24. https://doi.org/10.1016/j.actpsy.2012.02.001
[12] Pureza, J. R. Jacobsen, G. M. Oliveira, R. G. and Fonseca, R. P. (2011). Relationships between executive function tasks in late childhood. Psychology & Neuroscience, 4(3): 369-376. https://doi.org/10.3922/j.psns.2011.3.010
[13] Rudkin, S. J. Pearson, D. G. and Logie, R. H. (2007). Executive processes in visual and spatial working memory tasks. The Quarterly Journal of Experimental Psychology, 60(1): 79-100. https://doi.org/10.1080/17470210600587976
[14] Yates, D. B. Zibetti, M. R. Pawlowski, J. Salles, J. F. De Mattos Pimenta Parente, M. A. De Lima Argimon I. Fonseca, R. P. and Trentini, C. M. (2013). WCST and NEUPSILIN: Relationships among Executive Functions, Attention, Memory and Language. Psicologia: Reflexao e Critica, 26(3): 506-515. https://doi.org/10.1590/s0102-79722013000300010
[15] Cinan, S. and Tanor, O. O. (2002). An attempt to discriminate different types of executive functions in the Wisconsin Card Sorting Test. Memory, 10(4): 277-289. https://doi.org/10.1080/09658210143000399
[16] Nouchi, R. Taki, Y. Takeuchi, H. Nozawa, T. Sekiguchi, A. and Kawashima, R. (2016). Reading aloud and Solving simple arithmetic calculation intervention (Learning Therapy) improves inhibition, verbal episodic memory, focus attention and processing speed in healthy elderly people: Evidence from a randomized controlled trial. Frontiers in Human Neuroscience, 10(217): 1-14. https://doi.org/10.3389/fnhum.2016.00217
[17] Fried, R. Chan, J. Feinberg, L. Pope, A. Woodworth, K. Y. Faraone, S. V. and Biederman, J. (2016). Clinical correlates of working memory deficits in youth with and without ADHD: A controlled study. Journal of Clinical and Experimental Neuropsychology, 38(5): 487-496. https://doi.org/10.1080/13803395.2015.1127896
[18] Francesco, C. Francesco, M. Legrottaglie, A. R. Palumbi, R. De Giambattista, C. and Margari, L. (2016). A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder. Neuropsychiatric Disease and Treatment, 12: 1191-1202. https://doi.org/10.2147/ndt.s104620
[19] Mertes, C. Wascher, E. and Schneider, D. (2016). From capture to inhibition: How does irrelevant information influence visual search? Evidence from a spatial cuing paradigm. Frontiers in Human Neuroscience, 10(232): 1-13. https://doi.org/10.3389/fnhum.2016.00232
[20] Channon, S. (2004). Frontal lobe dysfunction and everyday problem solving: Social and non-social contributions. Acta Psychologica, 115: 235-254. https://doi.org/10.1016/j.actpsy.2003.12.008

[21] Beck, S. R. Williams, C. Cutting, N. Apperly, I. A. and Chappell, J. (2016). Individual differences in children's innovative problem-solving are not predicted by divergent thinking or executive functions. Philosophical Transactions Royal Society B, 371: 1-11. https://doi.org/10.1098/rstb.2015.0190

[22] Petrovic, P. and Castellanos, F. X. (2016). Top-down dysregulation-From ADHD to Emotional Instability. Frontiers in Human Neuroscience, 10(70): 1-25. https://doi.org/10.3389/fnbeh.2016.00070

[23] Jiang, W. Li, Y. Du, Y. and Fan, J. (2016). Emotional regulation and executive function deficits in unmedicated Chinese children with Oppositional Defiant Disorder. Psychiatry Investigation, 13(3): 277-287. https://doi.org/10.4306/pi.2016.13.3.277

[24] Van Stralen J. (2016). Emotional dysregulation in children with attention-deficit/hyperactivity disorder. ADHD Attention Deficit Hyperactivity Disorder, 1-13. https://doi.org/10.1007/s12402-016-0199-0

[25] Nguyen CM, Chen K-H and Denburg NL. (2018). The Use of Problem-Solving Therapy for Primary Care to Enhance Complex Decision-Making in Healthy Community-Dwelling Older Adults. Front. Psychol., 9(870) https://doi.org/10.3389/fpsyg.2018.00870

[26] Denburg, N. L., and Hedgcock, W. M. (2015). Age-associated executive dysfunction, the prefrontal cortex, and complex decision making, in Aging and Decision Making: Empirical and Applied Perspectives, eds T. M. Hess, J. Strough, and C. E. Lockenhoff. New York, NY: Academic Press, 81–104. https://doi.org/10.1016/b978-0-12-417148-0.00005-4

[27] Lezak, M. D., Howieson, D. B., Bigler, E. D., and Tranel, D. (2012). Neuropsychological Assessment, 5th Edn. New York, NY: Oxford University Press.

[28] Alexopoulos G. S., Raue, P.J., Kiosses, D.N. et al. (2011). Problem-Solving Therapy and Supportive Therapy in Older Adults with Major Depression and Executive Dysfunction. Arch Gen Psychiatry, 68(1): 33-41 https://doi.org/10.1001/archgenpsychiatry.2010.177

[29] Kurowski B.G., Stancin T. Taylor H.G. McNally K.A. Kirkwood M.W. Cassedy A. King E. Skluta M. Narad M.E. and Wade S.L. (2018). Comparative effectiveness of family problem-solving therapy (F-PST) for adolescents after traumatic brain injury: Protocol for a randomized, multicenter, clinical trial. Contemporary Clinical Trials Communications, 10: 111–120. https://doi.org/10.1016/j.conctc.2018.04.001

[30] Zelazo PD, Forston JL, Masten AS and Carlson SM. (2018). Mindfulness Plus Reflection Training: Effects on Executive Function in Early Childhood. Front. Psychol., 9(208) https://doi.org/10.3389/fpsyg.2018.00208

[31] Espinet, S. D., Anderson, J. E., and Zelazo, P. D. (2013). Reflection training improves executive function in preschool children: behavioral and neural effects. Dev. Cogn. Neurosci., 4: 3–15 https://doi.org/10.1016/j.dcn.2012.11.009

[32] Wood, D. and Middleton, D. (1975). A study of assisted problem-solving. British Journal of Psychology, 66: 181-191 https://doi.org/10.1111/j.2044-8295.1975.tb01454.x

[33] Borkowski, J. G., Chan, L.K.S. & Muthukrishna, N. (2000). A Process-Oriented Model of Metacognition: Links between Motivation and Executive Functioning. Issues in the Measurement of Metacognition, ed. Gregory Schraw & James C. Impara ,Lincoln, NE: Buros Institute of Mental Measurements.

[34] Senn, T.E. Andrews, K. Kaufmann, E. & P. (2004). Using Path Analysis to Understand Executive Function Organization in Preschool Children, Developmental Neuropsychology, 26(1): 445-464 https://doi.org/10.1207/s15326942dn2601_5

[35] Brock, L. Rimm-Kaufman, S.E. Nathanson, L. & Grimm, K.J. (2009). The contributions of 'hot' and 'cool' executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten, Early Childhood Research Quarterly, 24(3): 337-349, ISSN 0885-2006 https://doi.org/10.1016/j.ecresq.2009.06.001

[36] Riggs, N.R. Jahromi, L.B. Razza, R.P. Dillworth-Bart, J.E. & Mueller, U. (2006). Executive function and the promotion of social–emotional competence, Journal of Applied Developmental Psychology, 27(4): 300-309 https://doi.org/10.1016/j.appdev.2006.04.002

[37] Hughes, C. & Ensor, R. (2011). Individual differences in growth in executive function across the transition to school predict externalizing and internalizing behaviors and self-perceived academic success at 6 years of age, Journal of Experimental Child Psychology, 108(3): 663-676, ISSN 0022-0965 https://doi.org/10.1016/j.jecp.2010.06.005

[38] Rhoades, B.L. Greenberg, M.T. & Domitrovich, C.E. (2009). The contribution of inhibitory control to preschoolers' social–emotional competence, Journal of Applied Developmental Psychology, 30(3): 310-320 https://doi.org/10.1016/j.appdev.2008.12.012

[39] Barkley, R.A. (2010). Differential Diagnosis of Adults With ADHD: The Role of Executive Function and Self-Regulation. Supported by an educational grant from Eli Lilly and Company.

[40] Robertson, I. H. (1996). Goal Management Training: A Clinical Manual. Cambridge: PsyConsult.

[41] Levine, B., Stuss, D. T., Winocur, G., Binns, M. A., Fahy, L., Mandic, M., Bridges, K., and Robertson, I. H. (2007). Cognitive rehabilitation in the elderly: effects on strategic behavior in relation to goal management. J. Int. Neuropsychol. Soc., 13: 143–152. https://doi.org/10.1017/s1355617707070178

[42] Levine, B. Schweizer, TA. O'Connor, C. Turner, G. Gillingham, S. Stuss, DT. Manly T. and Robertson, IH. (2011). Rehabilitation of executive functioning in patients with frontal lobe brain damage with goal management training. Frontiers in Human Neuroscience, 5(9): 1-9 https://doi.org/10.3389/fnhum.2011.00009

[43] Kennedy M.R.T. & Coelho C. (2005). Self-Regulation after Traumatic Brain Injury: A Framework for Intervention of Memory and Problem Solving. Seminars in Speech and Language, 26(4). https://doi.org/10.1055/s-2005-922103

[44] Muscara, F., Catroppa, C. and Anderson, V. (2008). Social problem-solving skills as a mediator between executive function and long-term social outcome following paediatric traumatic brain injury. Journal of Neuropsychology, 2: 445-461, https://doi.org/10.1348/174866407x250820

[45] Skogli, E. W. Egeland, J. Andersen, P. N. Hovik, K. T. and Øie, M. (2013). Few differences in hot and cold executive functions in children and adolescents with combined and inattentive subtypes of ADHD. Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 1-23. https://doi.org/10.1080/09297049.2012.753998

[46] Zendel, B. R. De Boysson C. Mellah S. Demonet J.-F. and Belleville S. (2016). The impact of attentional training on event-related potentials in older adults. Neurobiology of Aging, 47: 10-22. https://doi.org/10.1016/j.neurobiolaging.2016.06.023

[47] Sperduti, M. Makowski, D. and Piolino, P. (2016). The protective role of long-term meditation on the decline of the executive component of attention in aging: a preliminary cross-sectional study. Aging, Neuropsychology and Cognition, 23(6): 691-702. https://doi.org/10.1080/13825585.2016.1159652.

[48] Wedelin, D and Adawi, T. (2014).Teaching Mathematical Modelling and Problem Solving - A Cognitive Apprenticeship Approach to Mathematics and Engineering Education. iJEP, 4(5), Special Issue: "CISPEE". https://doi.org/10.3991/ijep.v4i5.3555

[49] Zygouris, N.C. Vlachos, F. Dadaliaris, A.N. Oikonomou, P. Stamoulis, G.I. Vavougios, D. Nerantzaki, E. and Striftou, A. (2017). A Neuropsychological Approach of Developmental Dyscalculia and a Screening Test Via a Web Application. iJEP, 7(4). https://doi.org/10.3991/ijep.v7i4.7434

[50] Drigas, A. Karyotaki, M. and Skianis Ch. (2018). Mindfulness Training, Assessment and Intelligence. iJES, 6(3).
[51] Drigas, A. Karyotaki, M. and Skianis Ch. (2018). An Integrated Approach to Neuro-development Neuroplasticity and Cognitive improvement, iJES, 6(3). https://doi.org/10.3991/ijes.v6i3.9034
[52] Drigas, A. Skianis Ch. and Karyotaki, M. (2017). Success: A 9 Layered-based Model of Giftedness, iJES, 5(4). https://doi.org/10.3991/ijes.v5i4.7725

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Digital Entrepreneurship Education

The Role of MOOCs

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Abstract—Digital entrepreneurship has gained more attention in theory and practice in recent years. Among other forms of digital entrepreneurship education, MOOCs (massive open online courses) are one of the strongest trends and influence the content and flow of teaching and learning. The paper contributes to a better understanding of the necessary skills, opportunities and risks arising from the use of MOOCs as a new way of teaching entrepreneurship. It empirically examines challenges and drivers for the use of MOOCs as a novel pedagogical concept. The results show that a lack of self-discipline to complete a MOOC and a lack of interaction with others are the main obstacles compared to lectures with compulsory university attendance. However, the results also show that MOOCs are flexible in time and space and can thus facilitate the accessibility of education, especially entrepreneurial education.

Keywords—Digital entrepreneurship, digital entrepreneurship education, massive open online course, mooc

1 Introduction

Academic entrepreneurship has attracted major attention both within the academic literature and academic practice where it is considered to be an important element in the movement to become a knowledge society [1] An emerging perspective of academic entrepreneurship includes wider social and economic benefit to the university ecosystem overcoming the traditional goal of economic revenue from research commercialization. Today the creation of students and alumni start-ups, entrepreneurially equipped students, and job creation in the local region or state have become the priority [1].

We understand entrepreneurship as "the process of designing, launching and running a new business" [2] with its distinct characteristic of new value creation, though entrepreneurship is more than starting up a new business. Applying a holistic perspective, entrepreneurial activity arises of the interplay of institutions (e.g. education or business development), stakeholders and entrepreneurs themselves [3].

Parallel to the evolution of academic entrepreneurship, another interesting phenomenon is the rapid acceleration of digital technologies that in the past 10 years are reshaping the markets and society globally [1]. The infusion of new digital technologies,

such as mobile computing, cloud computing, social media, 3D printing, and data analytics into various aspects of innovation and entrepreneurship has transformed the nature of entrepreneurial processes and outcomes [4]. As the digitalization phenomenon causes various implications through rapid and transformative change, it is relevant for entrepreneurs and entrepreneurship researchers to be aware of related outcomes and connections and identify emerging opportunities on business [3].

Digitization has upended two assumptions that underlie our understanding of entrepreneurial processes and outcomes. First, digital technologies have rendered entrepreneurial outcomes and processes less bounded. We see a shift from discrete impermeable, and stable boundaries to increasingly porous and fluid boundaries [4]. In terms of outcomes, this relates to the structural boundaries of the product, service, etc. In terms of processes, this relates to the spatial and temporal boundaries of entrepreneurial activities. Digitization of products and services allows for greater flexibility by separating function from form and contents from medium. Second, digitization has led to less predefinition in the locus of entrepreneurial agency as it increasingly involves a broader, more diverse, and often continuously evolving set of actors [4].

The relevance of entrepreneurship education (EE) to foster entrepreneurship culture and activity is widely recognized. Entrepreneurial education provides key skills to identify a winning business. Teaching entrepreneurship has a number of positive effects and benefits. These benefits include the inculcation of thinking as well as collaborative and communication skills that are highly valued by employers [6].

Although more and more engineering students are being exposed to EE, minimal research has examined engineering student attitudes toward it, its impact on their learning, or professional competence. This is not surprising given the fact that the integration of entrepreneurship in engineering is a relatively new effort, where definitions of what it means to be entrepreneurial within an engineering program as well as program models vary greatly [7].

Compared to the increasing importance of digital entrepreneurship, surprisingly few papers address the teaching of digital entrepreneurship. Digital entrepreneurship education usually comes with low start-up and running costs. Thereby, teaching of digital entrepreneurship is not only a current hot topic but also feasible in many educational environments and directly addresses student's real life [3].

The paper at hand therefore discusses two questions. First, what are the necessary skills, opportunities and risks arising from the use of digital EE, specifically MOOCs, as a new way of teaching entrepreneurship? Second, what are the challenges and drivers for the use of MOOCs as a novel pedagogical concept?

2 The Concept of Digital Entrepreneurship

In recent decades, digital technologies have seen widespread use across global society and adoption at all levels of education. These digital technologies are opening up fascinating innovation opportunities for entrepreneurs [1]. New opportunities are quick to arise and vanish, combined resources unexpectedly acquire or lose their original value, and testing becomes a vital feature of the entrepreneurial learning process [8].

At the same time digital technology and associated entrepreneurship has not only sparked economic growth, but also competitive turbulence and creative destruction along with institutional change [9].

In this paper digital entrepreneurship is understood as "a subcategory of entrepreneurship in which some or all of what would be physical in a traditional organization has been digitized" [10]. Digital entrepreneurship is a phenomenon which arose through technological assets like internet and information and communications technology [3].

The concepts of academic entrepreneurship and entrepreneurship are closely linked, as both are based on the emergence of entrepreneurial opportunities in different contexts [11]. Digital academic entrepreneurship highly utilizes new digital technologies. From digital academic entrepreneurship different forms of academic entrepreneurship evolves, such as the development of digital spinoffs and alumni start-ups, the creation of entrepreneurial competence supported by digital platforms and a broader range of innovation development. Digital academic entrepreneurship engages more stakeholders through the use of digital technologies to develop the academic entrepreneurial process [1].

3 Digital Entrepreneurship Education

Today's classrooms are highly connected and provide both teachers and students easier, faster, and more affordable access to information, resources for learning and teaching as well as access to peers. Several studies proposed that EE cannot be taught with traditional methods [12]. Traditional education teaches students to obey, duplicate, and be employed while entrepreneurship tells students to make their own judgements and create their own jobs and these cannot be taught using traditional teaching [13].

Class-delivered lectures can be successfully replaced by rich media formats including videos, podcasts of lectures, online presentations or interactive content or online tutorials, and are effective in instructing large amounts of conceptual content [14]. Table 1 gives an overview of modern digital learning methodologies, tools and contexts.

Table 1. Digital learning methodologies, tools and contexts [15]

Methodologies, Tools and Contexts	Examples
Digital learning methodologies	Project based learning; problem based learning; digital stories; online learning environments; digital moments; technology integrated teaching methods; digital storytelling; educational games; authentic learning
Digital learning contexts	Collaborative communities; cooperative learning; digital combinational system; collaborative learning; flipped classroom using digital media; moving from fixing to online space; experiential online development; open educational practice; network participation
Tools and simulators	Web-based video; computerized environments; spatial science technology; slowmation: narrated stop-motion animation; generic modelling language; digital video; augmented reality; design based research; gamification; learning manager; simulation; computer based teaching; library webinars
Support system for digital learning	eLearning; mobile learning; learning object repository; blended learning; blackboard; moodle learning manager; twitter; videoconferencing; MOOC – massive open online courses

Video presentations can enable self-directed learning and provide effective overviews or vivid examples of different situations and cases. Videos may be focused on specific knowledge points or known problem concepts and practical problems [16].

From surveying students, the following advantages of videos over live lectures have been reported: Notes from video presentations were handy because they should not miss any content when writing; some students found it easier to focus attention on videos than in a live class. Most students watched the videos at appropriate times and watched them again to prepare for the exams. They spent more time on the topic than usual. The ability to watch, pause and rewind the video several times helped students understand the content, especially those struggling with language [10], while others preferred to listen to the topic being "spoken". Video also offers alternative representations of information and hosts various learners who prefer visuals, audio or text.

An investigation of viewing habits of videos revealed how adaptable students are in their frequency of video viewing, and how engaged they are while doing it. Results show that even though video engagement declined steadily during the semester, students tended to adapt, depending on factors such as exam difficulty and the value of the material. While the length of a lecture video had no effect on video engagement there was a noticeable trend in increasing total views. [17].

While the traditional lecture can be more effective at communicating information than supporting the development of skills, values or personal development, the value of digital learning is challenged when it is teacher-centered pedagogy [19]. Teacher-centered pedagogies that lack commitment or interaction often lead students to adopt a passive attitude to learning while encountering focus problems and not taking responsibility for their own learning. Moreover, the limited interaction makes it difficult for teachers to differentiate the pace and the teaching, which adapts to the different progress of learners [16, 20].

Distributed flipped classrooms (FC) with massive open online courses (MOOCs) open up new opportunities to provide online content resources such as videos and assignments when running alongside campus courses [16, 18]. However, FC may fail due to monotonous and impersonal video presentations, which can inevitably lead to loss of interest and poor teaching presence. The composition of a video affects how students choose to watch it. If videos are too complicated, lack visual change, or include portions with perceived minimal academic value, students shy away from, or skip through them [17].

Videos that present technology-delivered lectures aimed solely at the transmission of content are poor compared to well-planned interactive lectures. Videos can also be overrated as a teaching tool when students are unable to watch videos due to the unavailability of computers and the internet [21]. Therefore, the format of the variety of materials and activities used in different contexts is less important than ensuring that students actually accessed these materials. In addition, teachers find it difficult to find suitable videos, despite the extensive online offerings [16].

The most important component in an FC was the involvement of students in the face-to-face component. FC teachers agree that instructional videos alone do not improve teaching; it depends on how they are integrated into an overall approach [19]. A well integrated approach can spread the students' attitude to flipping, which is sometimes

negative because they perceive a higher workload or a lack of cohesion between classroom and extracurricular work.

4 Massive Open Online Courses (MOOCs) in Entrepreneurship Education

Massive open online courses (MOOCs) are changing the way in which people can access digital knowledge, thus creating new opportunities for learning and competence development. MOOCs leverage the free and open use of digitized material through supportive online systems. Many education providers have started to offer courses in different domains such as entrepreneurship tackling recent demands for better self-employability [22].

4.1 The emergence of MOOCs

MOOCs are one of the strongest trends in online education [22]. MOOCs as the name suggests are large-scale initiatives in the provision of online courses. They has appeared as a disruptive innovation that permits to engage a large number of persons in an open online course available through internet to anyone aiming to enroll [23]. MOOCs developed from the increasing expertise of the universities in the use of distance learning and open educational resources [24].

The multiple breakthroughs achieved by the MOOCs include the capacity to assemble some of the finest academics in the leading international universities, to develop what are often superb learning materials, and to offer the courses for free [24]. Leading universities such as Harvard, MIT and Stanford have launched MOOC platforms such as Udacity, Coursera, edX, MIT Open Courseware, and Stanford eCorner. The courses were realized with the help of various technological support for self-learning (papers, short videos about well focused contents, flash animation) and for synchronous and asynchronous interaction as well. Asynchronous delivery realizes the idea that anyone can approach education at any time and from anywhere; synchronous delivery requires learners to synchronize their learning activities with those of others [22].

In addition to individual learning, there are positive effects of online learning group processes reported recently [25]. MOOCs offer the possibility to learn online to a massive number of students, and part of their features is free of charge for the participants. Over the past few years, MOOCs have achieved a widespread, global profile. Enabled by technology, they have arisen from a mixture of experimentation with educational technology and pedagogic approaches [26]. MOOCs have a high potential to allow the massive development of knowledge and certain competences among adult learners' showing enough motivation, self-regulation [20] and cognitive quality time to engage, and succeed in this online courses. For this reason, MOOCs could be considered as an excellent opportunity to achieve education objectives among massive number of participants in informal contexts, such the development of an entrepreneurship culture [23].

MOOCs have four main characteristics. First of all, they are open to everyone, meaning that there are no entry requirements. Secondly, there is no participant restriction regarding the number of participants. Thirdly, the courses are offered free of charge. Fourthly, the courses are conducted completely online. Therefore, there are no technical laboratory phases [27].

MOOCs can be thus considered forerunners of course exemplars - early prototypes of improved learning environments which frequently recover flexible educational practice. The online courses are made for various target groups e.g. for school students, individuals or university students. Teachers are allowed to make selected learning materials available as Open Educational Resources (OER). Without violating copyrights, they can use the materials for the purpose of teaching [28].

However, there are also critical aspects when it comes to MOOCs. The problems often associated with distance education are the limited quality of the resources and materials supporting online learning, the interaction of students and academics, the high fees charged by premier online courses, and difficulties with assessment and accreditation [24].

Insights of media didactics regarding the structuring of the subject matter, the depth and speed with which content is conveyed and the design of performance reviews for learners are not yet sufficiently taken into account [29]. The open nature of MOOCs makes it challenging to show if any learning is taking place. Participants have a wide distribution of incoming knowledge, and very few courses impose prerequisites or try to measure the initial level [29].

Moreover, MOOCs have high abort rates. Depending on the course, only 2 to 10 percent of those who have registered for a course take the final examination [30]. The development, implementation and support of a MOOC involves considerable effort. This concerns the universities or university lecturers who are developing the courses. However, this also applies to the platform providers who make the courses available to participants [31].

4.2 MOOCs in entrepreneurship education

To prepare students for the new reality, universities are increasingly aware that they must graduate engineers who not only understand science and technology, but who are also able to identify opportunities, understand market forces, commercialize new products, and have the leadership and communication skills to advocate for them. This has prompted a significant increase in the delivery of EE to engineering students through new courses, programs, and experiential learning opportunities [14].

The massive development of MOOCs on entrepreneurship has been predominantly useful in providing digital content both inside and outside the classroom to students involved in entrepreneurship initiatives [21]. Free online courses on entrepreneurship also allow educators and students far away from pulsating business ecosystems to access a wider range of support, skills and content [6]. Researchers have studied the phenomenon in depth to understand the positive impact of social media engagement on the motivation, performance, course participation and completion of learners in MOOCs [1]. In addition, other researchers have focused their studies on evaluating the learning

outcomes of students in entrepreneurship courses offered as MOOCs. The results suggest that MOOC is an appropriate platform for teaching entrepreneurship, as it provides tools that enable students to facilitate collaborative learning and improve the most important affective entrepreneurial aspects of individuals, such as opportunity recognition and resource acquisition [6].

4.3 The MOOC "Start-up Journey" in entrepreneurship education

Students have plenty of ideas, from which many could be developed further, transferred to interesting business ideas and become the basis to set up a new company or startup. The path from the initiation of an idea to its implementation into a business model raises many questions and requires entrepreneurial competences as an obligatory prerequisite for founding a company.

Encouraging entrepreneurship has become a topic of high priority in the university policy of Graz University of Technology. Several entrepreneurial activities and lectures are offered, encompassing a MOOC in digital entrepreneurship education, the "Start-up Journey: Business Model Generation".

The MOOC "Start-up Journey" consists of four units with eight videos in total (two videos each unit), where one unit is offered weekly. The course doesn´t require any special prerequisites and aims to be used by students for their own business idea. Therefore, within the course basic knowledge and methods as well as their handling are imparted to gain the competence for generating a business model by the end of the course. Additionally, elements and methods are explained step-by-step, with a focus on the customer value as the reason why customers want to consume or purchase the product or service.

An important step in the foundation process is the creation of a business model. For this reason, students learn in the MOOC what a business model is and how to create one. Figure 1 shows an overview of the units of the MOOC "Start-up Journey: Business Model Generation". Unit 1 starts with an introduction of the topic with definitions, basics of the business model framework and patterns. Unit 2 explains, why the USP (unique selling point) is important, how customer value is identified and which helpful methods and tools can be used to fill in a business model canvas. Building up on this, the generation of a business model canvas is demonstrated in unit 3, using Tesla as an example. Optionally a task is given to create Lego´s business model canvas and a link to a possible solution is provided. To underline the practicability of the concept, two founders are interviewed in another video, giving an insight into their experiences with startups. To top off the "Start-up Journey" unit 4 provides experience reports with dos and don´ts when creating a business model canvas and how to successfully communicate the business idea with a pitch. Completing the "Start-up Journey", participants get an overview of helpful methods for their project and are able to create a business model for their own start-up idea.

For actively participating in the course students receive an automatic confirmation of participation (certificate) which confirms that the user answered at least 75 % of the self-assessment questions correctly. Furthermore, the MOOC can be completed by TU

Graz students as part of a corresponding course and is therefore provided with 1 ECTS as an elective subject.

Table 2. Overview of the modules of the MOOC "Startup-Journey: Business Model Generation"

MOOC Start-up Journey: Business Model Generation			
Unit 1	***Unit 2***	***Unit 3***	***Unit 4***
Business Model Patterns and Framework	**Customer Value**	**Business Model Generation**	**Experience Reports**
Business Model Framework Development	Identifying Customer Value	Generating a Business Model	Do´s and Don´ts
55 Business Model Patterns	Introduction of Entrepreneurship Methods	Business Model Journey Interviews	Pitch

4.4 Experiences with the MOOC "Start-up Journey"

To get an insight into student's experiences regarding MOOCs in EE, an empirical study was conducted in 2018. Students enrolled at the lectures "Entrepreneurship", "Gruendungsgarage" and "Process Management" held by the Institute of General Management and Organization at TU Graz were asked to take part in the study. Information was derived from 40 students who got in touch with MOOCs. The questionnaire used for this purpose consisted of 10 questions, whereby three of them were open ones.

Of the 40 respondents who were surveyed, 34 claimed that they have never attended a MOOC before participating. 7,5 % (k=3, n=40) respondents maintained that they have joined a MOOC several times before and 7,5 % only once before the three listed lectures.

Students were asked to evaluate different statements concerning MOOCs shown in figure 1. With reference to the data, it was stressed that 25 out of 40 students fully agreed to regularly use digital media for learning. However, only a small number of respondents expressed they would prefer a pure online course. Overall, students claimed that they would recommend the MOOC.

Additionally, students were asked about advantages and disadvantages in correlation with MOOCs. According to the ratings in figure 2, 39 out of 40 respondents claimed that time flexibility is a main advantage and 38 fully agreed on the local flexibility of MOOCs. Moreover, students appreciate the fact that there are no course fees, only 4 students disagreed little and 1 student fully disagreed. Overall, respondents also agreed on the fact that someone can adapt the online courses to the individual learning pace. Surprisingly, three respondents see it differently and disagreed little.

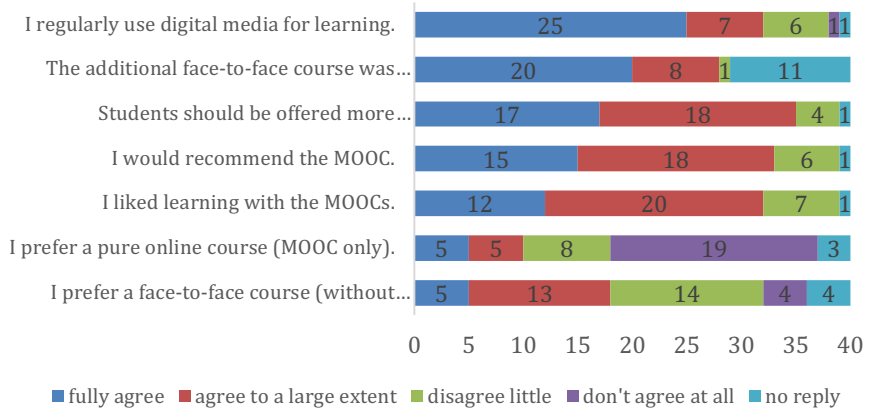

Fig. 1. Statements on MOOCs

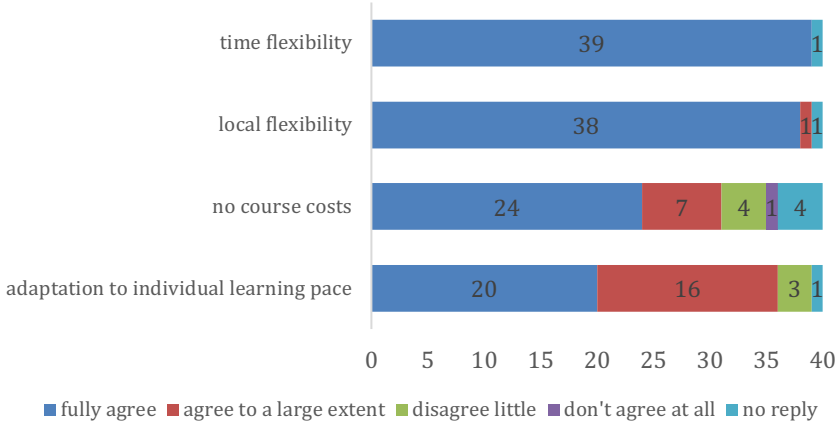

Fig. 2. Advantages of MOOCs

Several disadvantages in accordance with MOOCs have been stated in literature. The results of the survey show that 16 students (n=40) fully agree that "less exchange with fellow students" is a disadvantage (figure 3). It is interesting that 10 students claimed that they don't agree at all on the disadvantage that more motivation is required to complete a MOOC.

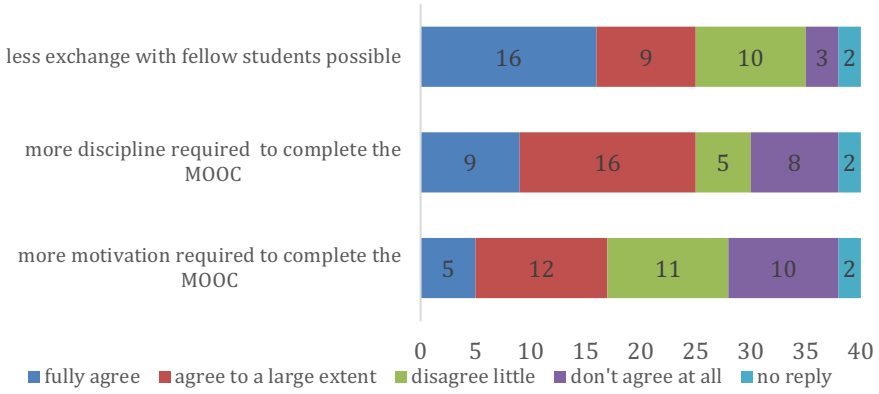

Fig. 3. Disadvantages of MOOCs

In addition, participants were asked to answer open questions about the MOOC to gain further insight and input for possible developments in future. As successful and well done in particular, participants perceived the MOOC as very understandable, professional and vividly explained with examples. The MOOC gives a good overview of the topic briefly, is available at any time, easy to use and a valuable supplement to lectures with physical presence. The quiz at the end of each unit of the MOOC was mentioned positively e.g. as a helpful tool for self-monitoring in the learning process. Challenges of digital EE using MOOCs were identified by the respondents too. The lack of self-discipline to finish the MOOC is mentioned as a hurdle compared to lectures with compulsory attendance at university. Challenges for lecturers were identified (e.g. costly to create to contents and develop the videos, need of special equipment and infrastructure for the video recording and production, focus on a small area of content) as well as for students who are confronted with theoretical input only online. Taking a course only online, respondents would miss the chance to ask the lecturer for rephrasing, discuss the content in real time and learning in interaction with others.

5 Conclusion and Outlook

Digital technologies are changing the way people do business and start new businesses. Universities start new initiatives to realize new forms of academic entrepreneurship. The debate on academic entrepreneurship should include a holistic perspective on this emerging phenomenon, according to the dimensions of why, what, who and how digital technologies will change academic entrepreneurship processes [1].

Digital technologies are ubiquitous and offer open and flexible opportunities that foster convergence and creativity. These technologies herald new forms of organization and new business models. Digital technologies mean that academic enterprises can use standardized tools to support academic business processes across the enterprise, and as a result more data and processes are shared across enterprise boundaries. This new way

of exchanging data and processes has implications for conventional configurations or relationships between the actors involved in academic business processes. Researchers and students in academia can now turn to a wider audience to discover new opportunities and reinforce their ideas [1].

MOOCs are changing the way people use and share digital knowledge, creating new opportunities for learning and skills development in market-relevant areas such as innovation management and entrepreneurship. MOOCs are predestined to reach a large audience that can enjoy the autonomy of self-directed teaching through the network of online peers. MOOCs can be seen as an appropriate tool to teach courses on entrepreneurship as they can increase personal entrepreneurial attitudes and inclinations, improve problem solving skills and facilitate the execution of multiple tasks. With its ease of scalability, operational flexibility and cost advantage, MOOCs can provide a large heterogeneous audience with economics and convenience in achieving education, especially entrepreneurship education.

But different to learning traditional subjects, entrepreneurial learning can best be disseminated through hands-on practical process, though the available pedagogy is deficient on this aspect. Further research therefore is required to evolve methods for improving cognitive skill, maintaining regularity and reducing dropouts. Given the large number of students to be catered to, it is essential to develop meaningful and cost-effective evaluation processes, innovate new meta-tutoring for effective learning, and make teaching increasingly practical.

6 References

[1] Rippa, P., & Secundo, G. (2018). Digital academic entrepreneurship: The potential of digital technologies on academic entrepreneurship. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2018.07.013

[2] Hsieh, Y.-J., & Wu, Y. J. (2018). Entrepreneurship through the platform strategy in the digital era: Insights and research opportunities. Computers in Human Behavior. https://doi.org/10.1016/j.chb.2018.03.033

[3] Kraus, S., Palmer, C., Kailer, N., Kallinger, F. L., & Spitzer, J. (2018). Digital entrepreneurship: A research agenda on new business models for the twenty-first century. International Journal of Entrepreneurial Behaviour and Research. https://doi.org/10.1108/IJEBR-06-2018-0425

[4] Nambisan, S. (2017). Digital Entrepreneurship: Toward a Digital Technology Perspective of Entrepreneurship. https://doi.org/10.1111/etap.12254

[5] Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital Innovation Management: Reinventing Innovation Management Research in a Digital World. MIS Quarterly. https://doi.org/10.25300/misq/2017/41:1.03

[6] Al-Atabi, M., & Deboer, J. (2014). Teaching entrepreneurship using Massive Open Online Course (MOOC). Technovation. https://doi.org/10.1016/j.technovation.2014.01.006

[7] Duval-Couetil, N., Reed-Rhoads, T., & Haghighi, S. (2012). Engineering students and entrepreneurship education: Involvement, attitudes and outcomes. International Journal of Engineering Education. 28(2). 425-435. https://doi.org/10.1109/fie.2011.6142996

[8] Ghezzi, A. (2018). Digital startups and the adoption and implementation of Lean Startup Approaches: Effectuation, Bricolage and Opportunity Creation in practice. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2018.09.017
[9] Geissinger, A., Laurell, C., Sandström, C., Eriksson, K., & Nykvist, R. (2018). Digital entrepreneurship and field conditions for institutional change– Investigating the enabling role of cities. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2018.06.019
[10] Hull, C. E., Hung, Y. T. C., Hair, N., Perotti, V., & DeMartino, R. (2007). Taking advantage of digital opportunities: a typology of digital entrepreneurship. International Journal of Networking and Virtual Organisations. https://doi.org/10.1504/ijnvo.2007.015166
[11] Siegel, D. S., & Wright, M. (2015). Academic Entrepreneurship: Time for a Rethink? British Journal of Management. https://doi.org/10.1111/1467-8551.12116
[12] Löbler, H. (2006). Learning entrepreneurship from a constructivist perspective. Technology Analysis and Strategic Management. https://doi.org/10.1080/09537320500520460, 18(1). 19-38.
[13] Chen, S. C., Hsiao, H. C., Chang, J. C., Chou, C. M., Chen, C. P., & Shen, C. H. (2015). Can the entrepreneurship course improve the entrepreneurial intentions of students? International Entrepreneurship and Management Journal. https://doi.org/10.1007/s11365-013-0293-0
[14] O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. Internet and Higher Education. https://doi.org/10.1016/j.iheduc.2015.02.002
[15] Sousa, M. J., Carmo, M., Gonçalves, A. C., Cruz, R., & Martins, J. M. (2018). Creating knowledge and entrepreneurial capacity for HE students with digital education methodologies: Differences in the perceptions of students and entrepreneurs. Journal of Business Research. 1–6. https://doi.org/10.1016/j.jbusres.2018.02.005
[16] le Roux, I., & Nagel, L. (2018). Seeking the best blend for deep learning in a flipped classroom – viewing student perceptions through the Community of Inquiry lens. International Journal of Educational Technology in Higher Education. https://doi.org/10.1186/s41239-018-0098-x
[17] Hildebrand, J., & Ahn, B. (2018). Student Video Viewing Habits in an Online Mechanics of Material Engineering Course. International Journal of Engineering Pedagogy (IJEP). https://10.3991/ijep.v8i3.7948
[18] Israel, M. J. (2015). Effectiveness of Integrating MOOCs in Traditional Classrooms for Undergraduate Students. International Review of Research in Open and Distributed Learning. 16(5). 102-115. https://doi.org/10.19173/irrodl.v16i5.2222
[19] Sams, A., & Bergmann, J. (2013). Flip Your Students' Learning The Best Use of Face Time. Technology-Rich Learning Pages. 70(6). 16–20.
[20] Onah, D. F. O., & Sinclair, J. E. (2017). Assessing Self-Regulation of Learning Dimensions in a Stand-alone MOOC Platform. International Journal of Engineering Pedagogy (IJEP). https://doi.org/10.3991/ijep.v7i2.6511
[21] Roehl, A., Linga, S., Gayla, R., & Shannon, J. (n.d.). The Flipped Classroom: An Opportunity To Engage Millennial Students Through Active Learning Strategies. 105(2). 44-48. https://doi.org/10.14307/jfcs105.2.12
[22] Cirulli, F., Elia, G., Lorenzo, G., Margherita, A., & Solazzo, G. (2016). The use of MOOCs to support personalized learning: An application in the technology entrepreneurship field. Knowledge Management and E-Learning. https://doi.org/10.34105/j.kmel.2016.08.008
[23] Milian, R. P., & Gurrisi, M. (1108). Education + Training. Education + Training. 59(9). 990–1006. Retrieved from https://doi.org/10.1108/et-12-2016-0183

[24] Clarke, T. (2013). The advance of the MOOCs (massive open online courses): The impending globalisation of business education? Education and Training. https://doi.org/10.1108/00400911311326036
[25] Mayende, G., Prinz, A., Isabwe, G. M. N., & Muyinda, P. B. (2017). Learning groups for MOOCs lessons for online learning in higher education. In Advances in Intelligent Systems and Computing. https://doi.org/10.3991/ijep.v7i2.6925
[26] Porter, S. (2015). In To MOOC or Not to MOOC, Chandos Publishing, 3-6, 2015
[27] Schulmeister, R. (2013). Massive Open Online Courses. Waxmann. 22-23, 32.
[28] Ebner, M., Kopp, M., Wittke, A., & Schön, S. (2015). Das O in MOOCs – über die Bedeutung freier Bildungsressourcen in frei zugänglichen Online-Kursen. HMD Praxis Der Wirtschaftsinformatik. https://doi.org/10.1365/s40702-014-0106-0
[29] Rayyan, S., Fredericks, C., Colvin, K. F., Liu, A., Teodorescu, R., Barrantes, A., Pawl, A., Seaton, D. T., Pritchard, D. E. (2016). A MOOC based on blended pedagogy. Journal of Computer Assisted Learning. https://doi.org/10.1111/jcal.12126
[30] Clark, D. (2013). MOOCs: Who's using MOOCs? 10 different target audiences. URL: http://donaldclarkplanb.blogspot.de/2013/04/moocs-whos-using-moocs-10-different.htm https://doi.org/10.1089/mooc.2013.0004l
[31] Treeck, T. van, Himpsl-Gutermann, K., & Robes, J. (2013). Offene und partizipative Lernkonzepte. E-Portfolios, MOOCs und Flipped Classrooms, peDOCS. 9-10.

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Towards Digitalization in Academic Start-ups

An Attempt to Classify Start-up Projects of the Gruendungsgarage

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Abstract—Founded in 2013 as a playground for implementation-oriented start-up ideas, the Gruendungsgarage is now an established academic start-up accelerator and an integral part of the regional start-up scene. Starting with a brief introduction to the program of the Gruendungsgarage as a best practice example with five years of experience in academic entrepreneurial education, a model with a practical-oriented focus for classifying the degree of digitalization in start-up projects is presented. Successful start-ups and promising start-up projects from the Gruendungsgarage are classified according to their degree of digitalization and illustrated by examples. Finally, implications for the practice in engineering education on entrepreneurship are derived and suggestions for future research are identified.

Keywords—Entrepreneurship education, digitalization, start-up accelerator

1 Introduction

As a cooperation between Graz University of Technology and University of Graz, the Gruendungsgarage is inter-university organized, interdisciplinary oriented and provides a convergence of scientific theory and entrepreneurial practice in the format of a course. Every semester students and employees of all universities apply for one of the ten coveted places to further develop their innovative start-up ideas within one semester at the Gruendungsgarage and, at best, to subsequently found a start-up. The participating start-up teams are professionally accompanied and supervised by the scientific staff of both universities as well as by qualified mentors who are professional experts in their field. Within the structured course of one semester at the Gruendungsgarage, basic knowledge about starting a business is acquired, the participants work on their own business plans and get coaching on the further improvement of their business ideas. Workshops on business model development, design thinking, online marketing, intellectual property rights, legal and tax consulting complete the preparation for the everyday business life of company founders. After the first pitch of the start-up ideas, each team defines development goals together with their mentor. The improved start-up projects as well as the goals´ achievement are presented at the interim and final presentation in front of sponsors, investors, faculty members and

personalities from the regional start-up scene. Figure 1 shows the course of the Gruendungsgarage within one volume, corresponding to one semester.

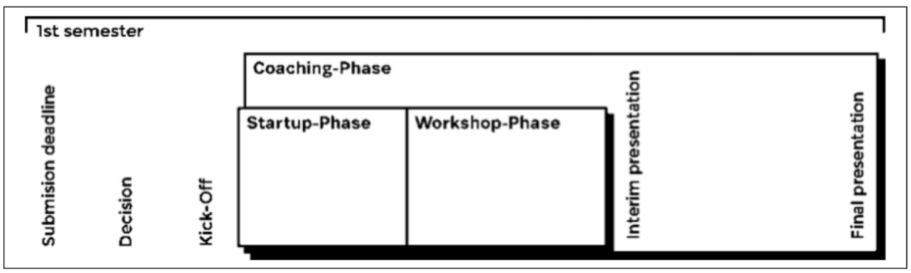


Fig. 1. Structure of the Gruendungsgarage [1]

Digitalization is progressing and is undoubtedly a megatrend with far-reaching implications. Investigating business models of the industry 4.0 Kaufmann [2] states, that products no longer consist only of hardware, especially the relevance of software is rising sharply and many products are being expanded by controls and communication modules in order to communicate. The technical possibilities and developments offer opportunities for business model innovations and new market participants arise [2]. Setting the focus on manufacturing, digitalization enables faster processes in product development, a more flexible production and increased efficiency regarding the use of resources. Therefore, costs can be significantly reduced while reliability, quality and process sustainability increase [3].

Digitalization also offers plenty of chances for start-ups and future entrepreneurs developing new business ideas. It is therefore of interest in this paper to examine the start-up projects of the Gruendungsgarage and to answer the questions as to whether the start-up projects are affected by digitalization and how the start-up projects can be classified accordingly. With regard to the aspects of digitalization, the start-up projects participating in the volumes I to X (ten semesters) of the Gruendungsgarage are examined in more detail in the present paper. Based on an initial, practice-oriented assessment, an attempt to classify the start-up projects is made. After analyzing the successful start-up projects of the Gruendungsgarage, implications for the entrepreneurship education, especially in the field of engineering education, are derived.

2 Classification Concept and Allocation of the Sample Start-ups

In the context of the digital transformation in society, economy and science, the start-ups (already founded or in the founding process) of the Gruendungsgarage are analyzed for the first time. A practice-oriented classification of the digitalization of start-up projects with a focus on the product, the process and the business model is carried out, adapting the concept of Matzler et al. [4].

After an investigation of several studies Rachinger et al [5] state, that digitalization affects and triggers changes in businesses and business models threefoldly – when

refining established business models, transforming established business models and developing novel business models [5]. Matzler et al. [4] also describe the impact of digitalization on three levels: At the level of products and services with customer value, the more efficiency-driven processes leading to more profound changes and at the level of the business model, combining data and data-driven services, creating new customer value and a new business logic.

Classifying a start-up´s business model predominantly into analogue, hybrid (a combination of digital and analogue) or digital is a new approach and therefore, only a first attempt is made in the present paper referring to the following definition of a digital business model by Veit et al. [9]: *"A business model is digital if changes in digital technologies trigger fundamental changes in the way business is carried out and revenues are generated"* [9, p.48].

In the present paper, the data generation and assessment of the digitalization on product, process and business model level was conducted on the basis of the projects documentation of the Gruendungsgarage and compared with the information available at the start-ups´ websites as well as personal response from the founded start-ups and start-up projects. Based on the current state of information on the founding projects, these are classified as predominantly digital, hybrid or analogue at each of the three levels and evaluated in a tabular form.

2.1 Classification of digitalization by examples

To classify the product into digital, hybrid and analogue at product and process level, the product was defined as a physical result or service for the customer and the process of service provision in terms of production and sales. An assessment of the business model was made with reference to the dimensions "Who, What, How and Why" of the business model by Gassmann [6] and the definition of Teece [7], according to which a business model describes the design and mechanisms for the creation, delivery and capture of value. Stated by Vendrell-Herrero et al. [8] digital technologies are drivers for change in the competitive market as companies develop new ways of generating, delivering and capturing value.

Using nine examples of founded projects, the classification into the levels of digitalization is demonstrated in Table 1. The clustering into predominantly digital, hybrid or analogue answers the questions in which form value is offered (product), how value is provided and distributed (process) and how revenue is generated (business model).

In Table 2 three examples of successfully founded and established start-ups of the Gruendungsgarage Graz are investigated in more detail. Studo, the app from the start-up project Moshbit is classified as digital on all levels of focus: digital product, digital processes and digital business model. Drone Rescue Systems is evaluated hybrid, as the product, the processes for delivering value, and the business model consist of both, analogue and digital components. Mehlspeisenfräulein with individually handmade confectionery and pastries is considered an analogue example, whereby the use of digital media for communication, social media and operating a website are left aside in this classification.

Table 1. Classification of nine examples of start-up projects into the levels of digitalization

	Product	Process	Business Model
Digital	Crosscloud Crosscloud's digital product enables companies to control and secure the use of various cloud storage services such as Dropbox or OneDrive in an enterprise.	TeLLers A digital feedback tool developed for the gastronomy industry. Trends and improvement potentials are derived directly from the opinions. Simple, anonymous and fast, the feedback is made easier for customers and operators.	Moshbit (Studo) Moshbit's Studo is an app for the digitalization of universities. It is used for organizing the individual everyday life of students, for work-load surveys of studies and evaluation of courses as well as a job portal for students.
Hybrid	Timeular (Zei) Timeluar's physical "Zei" octahedron simplifies and optimizes time recording in companies by assigning each page to a task or project and automatically recording the time via software as the octahedron is rotated.	Accessio (Arivo) Arivo facilitates people with the access to parking lots and the management of parking areas. The smart software combined with an automated licence plate recognition system is used for offices and residential properties.	Drone Rescue Systems The innovative system automatically detects a fall and ejects a rescue parachute. The drone is safely brought to the ground, damage is minimized and the data relevant to the user is processed through digital networking.
Analogue	Kobatani Flip-flops (shoes) made from recycled car tires.	Mehlspeisenfräulein Confectionery with pastries on an order basis only.	Doro-Turbine Small and economical hydropower turbine.

Table 2. Classification demonstrated in detail using three examples

	Product	Process	Business Model
Studo **digital**	**Studo** App for the digitalization of universities, organization of everyday studies and job portal.	Course Management, search Function, data collection, processing and networking.	Digitalization, Solution Provider, Two-sided Market.
DRONE OR RESCUE **hybrid**	**Drone Rescue** System with a physical parachute, digital web portal and app.	Fall protection by a physical parachute, data collection, processing and networking.	Cross-Selling, Subscription, Leverage Customer Data.
 **analogue**	Physical confectionery and pastries made by **Mehlspeisenfräulein**.	Individually handmade production in a bakery and physical delivery.	Ultimate Luxury, Solution Provider.

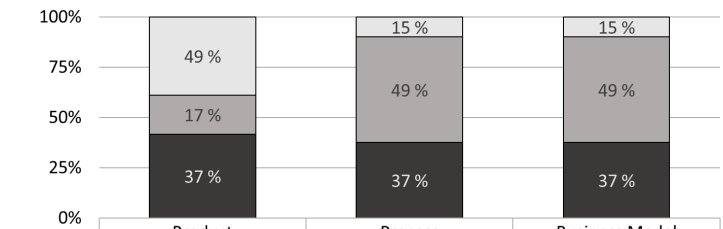
Taking a closer look at the start-up projects, in Table 2 the business model patterns according to Gassmann, Frankenberger and Csik [6] are used to sketch the business models. Not every single business model pattern that is identified has compulsory digital aspects. The patterns are adjusted and combined by the start-up projects and attributed to the classification in this first analysis based on the information available.

2.2 Analysis of the digitalization over ten semesters

After ten semesters of the Gruendungsgarage a positive summary can be given: Over the past five years, 91 teams have participated in the academic start-up accelerator program Gruendungsgarage, of which 25 start-up project ideas have resulted in founded start-ups with more than 130 jobs created. A further 16 projects are currently in the start-up founding phase and are about to enter the market.

The analysis and classification of the total of 41 projects of the Gruendungsgarage (25 founded start-ups plus 16 promising start-up projects) in terms of digitalization was carried out as these have already gained a foothold in the market or have the best prospects of establishing themselves.

The overview of the number of analogue, hybrid and digital products, processes and business models shown in Figure 2 provides information about the degree of digitalization of the start-ups and start-up-ready projects of the Gruendungsgarage.



	Product	Process	Business Model
analogue	14	4	4
hybrid	7	21	21
digital	15	15	15

Fig. 2. Levels of digitalization of start-ups and start-up projects of the Gruendungsgarage

The 41 analyzed projects of the Gruendungsgarage clearly show a focus towards digitalization. While at product level 19 of the start-up projects are classified as analogue, 7 as hybrid and 15 as digital, this ratio changes dramatically at process level. About the half of the teams (49 %, 19 teams) already founded or currently in the founding process rely on analogue products or services, but integrate the aspect of digitalization at the process level. Only 12 % implement a largely analogue business model. All of the start-ups use digital technologies for communication and web presence, but this fact is not considered as a digitalizing element of the business model. A total of 88 % of the projects of the Gruendungsgarage (37 % digital and 51 % hybrid) are characterized by digitalization in their business model.

In the case of the start-up projects with digital products (37 %), the dominant focus on digitalization is asserting itself to the same extent at the process level (37 %) and is also reflected in the business model (37 %). This phenomenon corresponds to the result considering the start-ups that have already been founded only, where 36 % have digital products, digital processes and digital business models.

Figure 3 shows the classification of the start-up projects´ business models over the course of all ten volumes (semesters) of the Gruendungsgarage. Six out of the ten

volumes are characterized by start-up projects with digital and hybrid business models only. Although no clear trend can be derived from the graph, it is shown that aspects of digitization have played a role across all volumes.

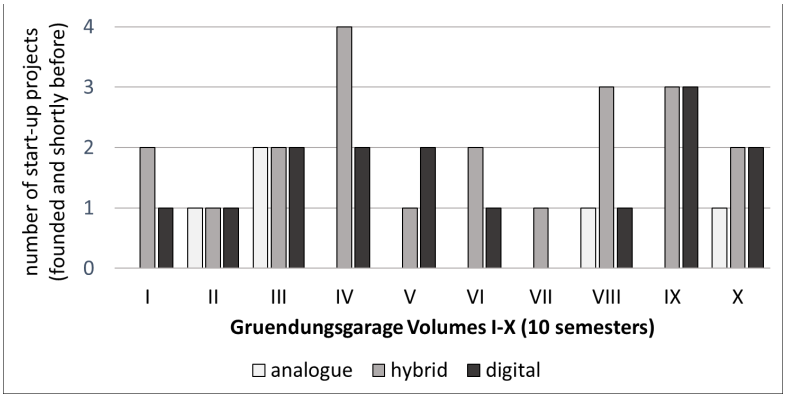


Fig. 3. Digitalization of the start-up projects business models over time

3 Conclusion and Implications

The focus towards digitalization is revealed by analyzing the start-ups and current projects of the Gruendungsgarage. The analysis shows that analogue products are increasingly extended by services in order to achieve unique selling points. These services are usually provided in digital form, for example by storing and evaluating data or networking devices. Therefore, nowadays an early consideration of the topic of digitalization seems indispensable in the founding process of a business.

Digital enterprises are empowered by new information and communication technology systems that integrate the following three technological keys according to Loonam et al. [10]: virtualization (for example cloud technology), mobility (such as social media, internet of things or mobile devices), and embedded analytics (like big data). These technologies coupled with embedded enterprise solutions enable the digital enterprise [10] and can also been seen as a point of origin to be promoted for developing new start-up ideas in the academic field.

Müller et al. [11] show that the lead of American companies regarding the degree of digitalization compared to German companies is also reflected in the implications of their digitalization activities. For example, performance goals can be achieved, sales can be increased and costs reduced. For start-ups, it is interesting to note that digitalization enables to open up new markets and enhance the company´s image [11], a fact that could also be taken into account when promoting the Gruendungsgarage.

Another tendency is that many business ideas require programming knowledge or digital skills, which the idea providers are often lacking themselves. Therefore, in addition to basic user knowledge, other topics of digital education (raising awareness on the relevance of digitalization as well as basic knowledge in programming) should be integrated into curricula and cross-study training formats. The masterplan of the

Austrian Federal Ministry of Education, Science and Research for the digitalization of the Austrian educational system aims to provide orientation for three fields of action: software, hardware and teaching [12]. Starting with the school year of 2018/2019, curricula of all secondary level I schools in Austria cover basic education in digital competencies based on successful projects on "Digital Basic Education" [13]. Nevertheless, a continuation of the digital education on an academic level seems reasonable.

Lindner [14] provides starting points for the entrepreneurship education of seven different target groups. The start-up teams participating in the Gruendungsgarage can be assigned to the target group four of entrepreneurship education programs as the attempt to implement, the behavioral intention and the business idea are present. Hence, the Gruendungsgarage should continue to focus on the further specification of the business idea and competence development for founders.

Sedelmaier and Landes [15] investigated the skills needed by requirements engineers at present and propose a set of competencies as a basis for the development of learning situations, which could also be of interest in the entrepreneurship education at the Gruendungsgarage. With entrepreneurship education as a cornerstone in engineering education, Holzmann et al. [16] provide insights from the Entrepreneurial Campus Villach, which could be considered as a case to elaborate on similarities and differences comparing it to the programs already offered in Graz.

In engineering education on entrepreneurship, especially in the Gruendungsgarage, it is worth considering how to better support teams with digital business ideas or start-up ideas that require digital components. For example, the range of workshops can be extended and the pool of mentors broadened to include more people with expertise in digitalization. A further initiative could be launched to match people willing to set up a business with programmers. In addition to making entrepreneurship education even more attractive, the inter-university and interdisciplinary cooperation contributes significantly to the success of the Gruendungsgarage and will therefore be continued.

4 References

[1] H. Höller and S. Vorbach, "Entrepreneurship in Engineering Education: The Example of Graz University of Technology," in *Interactive Collaborative Learning: Proceedings of the 19th ICL Conference - Volume 2*, M. E. Auer, D. Guralnick and J. Uhomoibhi, Eds., Springer, pp. 486-499, 2017. https://doi.org/10.1007/978-3-319-50340-0

[2] T. Kaufmann, *Geschäftsmodelle in Industrie 4.0 und dem Internet der Dinge: Der Weg vom Anspruch in die Wirklichkeit.* Wiesbaden: Springer Fachmedien, 2015.

[3] D. A. Martin, "Shaping the Digital Future in Education – Together," *International Journal of Engineering Pedagogy (iJEP),* vol. 8, *(2),* pp. 7-9, 2018. https://doi.org/10.3991/ijep.v8i2.8228

[4] K. Matzler, F. Bailom, S. F. von den Eichen, and M. Anschober, *Digital Disruption: Wie Sie Ihr Unternehmen auf das digitale Zeitalter vorbereiten.* München: Vahlen, 2016. https://doi.org/10.15358/9783800653799

[5] M. Rachinger, R. Rauter, C. Müller, W. Vorraber, and E. Schirgi, "Digitalization and its influence on business model innovation," *Journal of Manufacturing Technology Management,* 2018. https://doi.org/10.1108/JMTM-01-2018-0020

[6] O. Gassmann, K. Frankenberger, and M. Csik, *Geschäftsmodelle entwickeln: 55 Innovative Konzepte mit dem St. Galler Business Model Navigator.* München: Hanser, 2013.
[7] D. J. Teece, "Business Models, Business Strategy and Innovation," *Long Range Planning,* vol. 43, *(2),* pp. 172-194, 2010. https://doi.org/10.1016/j.lrp.2009.07.003
[8] F. Vendrell-Herrero, G. Parry, O. F. Bustinza, and E. Gomes, "Digital business models: Taxonomy and future research avenues," *Strategic Change,* vol. 27, *(2),* pp. 87-90, 2018. https://doi.org/10.1002/jsc.2183
[9] J. Loonam, S. Eaves, V. Kumar and G. Parry, "Towards digital transformation: Lessons learned from traditional organizations," *Strategic Change*, vol. 27, *(2)*, pp. 101-109, 2018. https://doi.org/10.1002/jsc.2185
[10] D. Veit, E. Clemons, A. Benlian, P. Buxmann, T. Hess, D. Kundisch, J. M. Leimeister, P. Loos, and M. Spann, "Business Models: An Information Systems Research Agenda," *Business & Information Systems Engineering,* vol. 6, *(1),* pp. 45-53, 2014. https://doi.org/10.1007/s12599-013-0308-y
[11] S. C. Müller, M. Böhm, M. Schröer, A. Bahkirev, B. C. Baiasu, H. Krcmar, and I. M. Welpe, Geschäftsmodelle in der digitalen Wirtschaft. Vollstudie, Studien zum deutschen Innovationssystem, No. 13-2016, Expertenkommission Forschung und Innovation (EFI), Berlin, 2016. Available: http://hdl.handle.net/10419/156641 [Accessed Nov. 15, 2018].
[12] Bundesministerium für Bildung, Wissenschaft und Forschung, "Masterplan für die Digitalisierung im Bildungswesen," Available: https://bildung.bmbwf.gv.at/schulen/schule40 [Accessed Nov. 15, 2018].
[13] Bundesministerium für Bildung, Wissenschaft und Forschung, "Digitale Grundbildung," Available: https://bildung.bmbwf.gv.at/schulen/schule40/dgb [Accessed Nov. 15, 2018].
[14] J. Lindner, "Entrepreneurship Education," in *Handbuch Entrepreneurship*, G. Faltin, Eds. Wiesbaden: Springer Reference Wirtschaft, Springer Gabler, pp. 407-423, 2018. https://doi.org/10.1007/978-3-658-04994-2_35
[15] Y. Sedelmaier and D. Landes, "How Can We Find Out What Makes a Good Requirements Engineer in the Age of Digitalization?" *International Journal of Engineering Pedagogy (iJEP),* vol. 7, *(3),* pp. 147-164, 2017. https://doi.org/10.3991/ijep.v7i3.7424
[16] P. Holzmann, E. Hartlieb and M. Roth, "From Engineer to Entrepreneur - Entrepreneurship Education for Engineering Students: The Case of the Entrepreneurial Campus Villach," *International Journal of Engineering Pedagogy (iJEP),* vol. 8, *(3),* pp. 28-39, 2018. https://doi.org/10.3991/ijep.v8i3.7942

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