How to create an ecosystem for engineering education to prepare future professionals to sustain in a fast changing and dynamic environment?

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Abstract

Preparing the professional of the future demands an approach in which the impact of emerging technologies and its influence on three main factors - human, environment and facilities - are considered. We build and facilitated an educational playground where multidisciplinary teams consisting of a diversity of learners, lecturers and researchers work together in close collaboration with the industry on real world applied research projects while using and learning about emerging technologies.

Unleashing the potential of learners

We know that technology is a means – not a goal - to add value to society. To incorporate this insight as a mindset, could be a valuable asset for innovative experiences and development in engineering education (curriculum design). It also gives new insights in how to implement technology enhanced active learning to engage and support learners in to taking full control of their study- and professional career development (ownership). This mindset results in a new educational and sustainable ecosystem consisting of a model (CETS) and roadmap with the following goals:

- Stronger and intensive cooperation between industry, education and government (University-Business Cooperation, Triple Helix) creating partnerships for applied research and engineering projects;
- Attractive, up to date and state of the art engineering programs;
- Further professionalizing of the universities work force.

By implementing the 'Connecting Education Technology and Science'-model we have achieved the following goals in two years:

- We build a strong network of knowledgeable companies which are more than willing to participate and contribute in our education;
- We developed educational programs together with the industry and interdisciplinary business units from Fontys UAS which make cooperation more approachable;
- We build an open educational playground in which the human factor, environment, and facilities are interconnected and offer new opportunities for future developments and research in teaching and in learning.

The ecosystem is an inspiration and source for other organizations to join and to co-create new educational and technological developments. We explore new ways of teaching- and learning methods and develop supporting (ICT) technology to create an educational environment which give learners control over their own learning needs and learning path.

Keywords: ecosystem, emerging technologies, talent development, customized learning

Introduction

There is a great shortage and demand for professionals with specialized technical skills (Brainport, 2014), but currently, technical skills are not the only requirements the industry is calling for (Engineering, 2004). Engineers are expected to be skilled and have knowledge of a broad professional spectrum: multidisciplinary team work, communication, sustainability, (local) manufacturing, combining art, design and engineering, innovation and creativity and global markets (entrepreneurship) are just a few examples (Engineering, 2004).

Universities face a challenge to educate and prepare engineering professionals for jobs increasingly involving multidisciplinary skill sets and for jobs that even do not exist yet (Dunn, 2011) (Forum, 2016). To succeed in both today's world and the future, we need to think and act differently (Kotter, 2014). This raises the question of how universities can adapt to fast changing technologies and the increasing demand for more, distinctive and broader qualified engineering professionals who are able to adapt and persist in the evolving digital economy.

Fontys University is fully aware of the dynamics and significant (economic) potential of the high-end and high-tech industry. Therefore, in 2014, a Centre of Expertise "Fontys Objexlab" was set up to improve and facilitate the link between education and applied research. Fontys University plays an important role in the regional innovation system as an industry partner and it is leading the way in higher education in advanced emerging technologies. To set up Objexlab the "Connecting Engineering Technology and Science" model (C.E.T.S. model) was used to formulate goals (Abdoel, Kawarmala, & Verwaal, 2014).

In 2016 we can confirm that all goals of the Centre of Expertise were achieved. We achieved stronger and intensive cooperation between industry, education and government by branding, PR, marketing and being present at relevant fairs and conferences. The core team of lecturers have been visiting fairs and conference and following training programs to professionalize themselves in the field and keep themselves updated. This knowledge will be applied directly in education and passed on to students. Currently, several applied research projects have started in collaboration with companies, lecturers and students. New knowledge and skills have been offered as workshops and training for the industry (Abdoel, Kawarmala, & Verwaal, 2014).

At present, two minor programs are developed and executed to answer to the need for updated and state of the art engineering bachelor programs in which learners develop competences, characteristics and skills required for jobs in the industry. For the near future, Objexlab aims to facilitate national and international learners to become the professional engineer of the future by developing curricula (bachelor, associate degree, minor) in which applied research is sustainably embedded (Abdoel, Kawarmala, & Verwaal, 2014).

Now that Fontys Objexlab is ready to operate fully, the next step is to employ the interaction and effects of the three factors: human, environment and facilities. To do this, a common ground starting point, or a vision on education ecosystem, was developed to elaborate the C.E.T.S. model for designing educational programs.

The present paper describes the models for developing and executing new education programs. These models for developing (3C model) and executing (Circle of Five) education, are elaborations of the C.E.T.S. model, particularly focusing on learning in education and applied research. The implementation of this new approach towards learning was measured and analyzed and will be presented in this paper.

1 Vision on education programs

Fontys Objexlab aims to design and develop programs, in which learners are triggered to develop a pro-active attitude, develop a healthy research mentality, manage their own time, to strive for excellence, to be meaningfully and actively engaged, take full advantage of opportunities, to focus quality and to challenge and relevance of the subjects they are studying or researching. To create common ground with a variety in multidisciplinary educational designers, the 3C model was introduced.

1.1 Starting point for developing education: 3C model

The 3C model consists of three elements Objexlab focusses on in developing educational programs: Collaboration, Co-Creation and Control. New education programs should include more *collaboration* in multidisciplinary student teams with the industry to work on real world applications using and learning about emerging technologies. Another rather new approach to designing education, is that the industry and other institutes are invited to *co-create* educational programs. The past two years this model has been an inspiration and source for other organizations and bachelor programs from different disciplines and institutes to join and to co-create new educational and technological developments (Abdoel, 2015). Finally, the design of the education should give learners *control* over their own learning needs and learning path.

1.2 Starting point for execution of education: Circle of Five

The Circle of Five focusses on changing the mindset and seeing the bigger picture. In this case this works two ways. Educators should practice what they teach. It means giving the example as a good role model. Other than that the learner should experience and be purposeful engaged to change their mindset to prepare themselves for the future.

Focus on the positive
We believe that learners are motivated and become self-aware when we focus on the positive of their learning journey. Focus on what they know and their progression and not on what they don't know (yet) and what went wrong. With focus on positivity, we want to support talent development and self-directedness of every learner.

Trust gives ownership
We trust our learners to take their own responsibility for their learning path. We give personal attention and freedom to learners who need freedom and give guidance and coaching to learners who need guidance and coaching. We believe that a motivated learner is able to assess himself on his competences for work, life and society. A motivated learner sees education as a privilege not as an obligation.

Providing challenge for every learner
This means not too difficult and not to easy assignments and variation of theoretical and active learning opportunities (specialist vs generalist). Also this means that the level can vary from learner to learner (self-paced, personalized learning combined with talent development). We believe that a learner is challenged by growth and attention for his/her unique talents and their personal ambitions.

Cohesion in development of education
Every educational program should start with the "big picture" and should be approached holistically. Cohesion in modules, subjects and study activities increases the learning potential for learners. Learning is multidimensional, therefore, in developing the modules and educational activities, peer consultation and involvement of experts from the industry and the learner's vision is seen as high value for our education in design, creation, development and execution.

Lean education
We prefer education as lean and transparent as possible in organization, structure, and in the design and development of programs and learning activities. We benchmark and back-up our programs with sound research and similar programs which have proven their quality in practice (Emiliani, 2015).

The 3C model and Circle of Five were used to design and execute three minor programs.

1.3 Minor programs with emerging technologies

The following minors were developed in 2015. The first minor "Smart Product Development with Additive Manufacturing" (SPDwAM) is a technical minor (specialist). The second minor "From Idea to Product with 3D printing" (FI2Pw3DP) is a broad minor (generalist) focusing on 3D printing and combining multidisciplinary aspects, such as Business and Design, of this technology in one program. The third minor is a "hybrid" minor "the Engineering minor". Students can choose a module and a project for 14 ECTS of "SPDwAM". The residual 16 ECTS consists of a combination of different modules from different engineering disciplines (automotive, electrical, mechanical and mechatronics).

In development and execution of all minors, preferences of the industry were taken into account, as well as the T-shaped competence model as presented in **Error! Reference source not found.** (Weggeman, 2010).

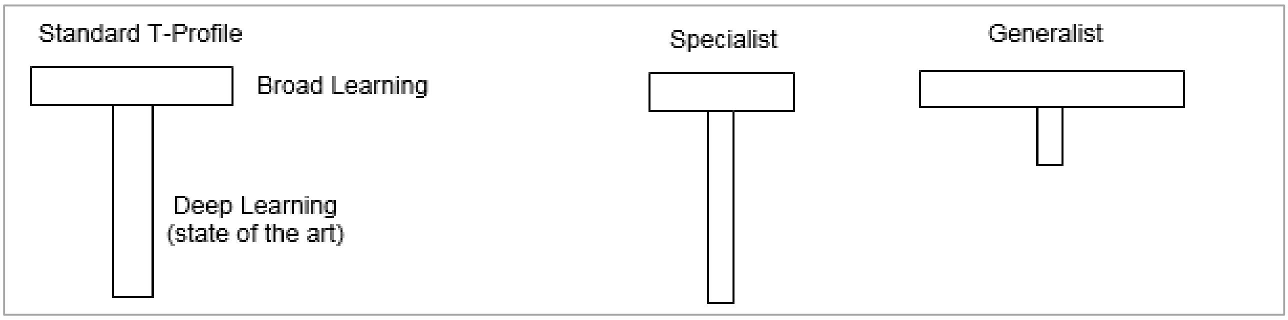

Figure 1. T-shaped competence model

The minors SPDwAM and FI2Pw3DP were designed, developed, executed and supervised by the educational designers of Objexlab. See Table 1 for a summary of characteristics of the minors.

Table 1. Summary of the three minors.

	Minor SPDwAM	Minor FI2Pw3DP	Engineering Minor
Development starting point	3C model	3C model	Hybrid
Executional starting point	Circle of Five	Circle of Five	Hybrid
Current educational designers and lecturers	6 lecturers of the Mechanical Engineering Department	15 lecturers of 9 different Fontys institutes with different technical and non-technical backgrounds	6 lecturers of the Mechanical Engineering Department + 3 lecturers of Fontys School of Engineering
Current students	5 Mechanical Engineering, 4 Automotive, 2 Mechatronics of Fontys School of Engineering	27 National Bachelor students with 12 different technical and non-technical backgrounds	20 Mechanical Engineering, 12 Mechatronics of Fontys School of Engineering
EC	30 EC	30 EC	14 EC SPDwAM / 16 EC Traditional
Duration	Feb 2016 – Jul 2016	Feb 2016 – Jul 2016	Feb 2016 – Jul 2016
Status	Pilot	Pilot	Embedded in Curriculum
Requirement	Propaedeutic exam + technical basic knowledge	Propaedeutic exam	Propaedeutic exam + technical basic knowledge
Team cooperation in product development	Multidisciplinary	Interdisciplinary	Multidisciplinary
Purpose	Trans-disciplinary	Multidisciplinary	Trans-disciplinary

The cross reference or connection of the competences, character qualities and skills with the learning activities and the expected/desired outcome were incorporated by implementing a diversity of active learning activities in different environments. For example: competition, guest lectures, company visits, poster presentations, pitching and storytelling, mini-symposium, visiting fairs and conferences, company projects, in-class assignments, weekly tutor meetings, peer assessments, progress and reflection by updating a weekly blog on a website, pressure cooker assignments, etc.

In the next chapter we research to what extent minor students recognize the vision of the education ecosystem in their minor program and if there are differences in groups in recognizing the vision of the education ecosystem in their minor program.

2 Method

2.1 Data collection

This research was carried out to obtain insight in the extent of recognition of the proposed vision of the education ecosystem, by students who are currently following one of the three minors: Smart Product Development with Additive Manufacturing (SPDwAM), From Idea to Product with 3D Printing (FI2Pw3DP) and the Engineering Minor. Additionally, we are interested if and which of these minor-groups differ from each other in recognizing the vision of the education ecosystem.

2.2 Respondents

A total of 70 minor students (11 SPDwAM, 27 FI2Pw3DP and 32 Engineering minor) were approached to fill out a questionnaire with statements about the proposed education ecosystem (3C model and Circle of Five). The questionnaire was distributed by e-mail in March 2016 after four weeks of education (at 25% of completion of the minor program) as a baseline measurement. At the end of the semester (July 2016) a second measurement will be executed to analyze and correlate the final minor grades of the students and their feedback to the baseline measurement.

2.3 Measurement instruments

Google Forms was used to design a questionnaire about the vision of the education ecosystem. The questionnaire consists of 40 items, formulated as statements, with answers from 'totally disagree' to 'totally agree' on a 5-point Likert scale. The questionnaire consists of several categories to distinguish the 3C model, Circle of Five and the Desired Outcomes. The 3C model is divided into three categories: Collaboration (Col), Co-Creation (Coc) and Control (Con). The Circle of Five is divided into five categories: Focus on the Positive (FOP), Providing Challenge for Every Student (CFES), Trust Gives Ownership (TGO), Cohesion in Development (CID) and Lean Education (LED). The last part of the questionnaire consisted of eight statements concerning Desired Outcomes: Pro-Active Attitude (PAA), Research Mentality (RM), Manage Time (MT), Strive for Excellence (SFE), Meaningfully and Actively Engaged (MAE), Take Full Advantage of Opportunities (TFAO), Focus on Quality (FOC) and Subjects Relevant and Challenging (SRC).

2.4 Analysis

To check the internal consistency of the questionnaire Cronbach's Alpha was calculated with IBM SPSS Statistics 24. To find an answer to the first research question "To what extent do our current minor students recognize the vision of the education ecosystem in their minor program?" percentages and mean scores were calculated of every category. To find an answer to the second research question *"Are there differences in groups in recognizing the vision of the education ecosystem in their minor program?"* we performed a one-way ANOVA and a post-hoc Scheffe test to find out which groups differ from each other on which category.

3 Results

3.1 Statistics

Response rate

Out of 70 distributed questionnaires a total of n = 44 respondents participated (response rate 63%). The respondent groups consist of 10 minor SPDwAM students (91% response rate), 10 minor FI2Pw3DP students (37% response rate) and 24 Engineering minor students (75% response rate).

Internal consistency reliability analysis

To check the reliability of the questionnaire we calculated Cronbach's Alpha for the categories of the 3C model, the Circle of Five and the Desired Outcomes. Additionally, we calculated Cronbach's Alpha for the whole questionnaire education ecosystem. We consider a Cronbach's Alpha of ≥ .70 as an indicator of sufficient reliability. Cronbach's Alpha ≤ 0.50 is seen as insufficient reliability. The results are listed in

Table 1.

Table 1. Internal consistency reliability analysis.

	Cronbach's Alpha
education ecosystem	.930
3C model	.573**
Collaboration	.683**
Co-creation	*
Control	.788
Circle of Five	.931
FOP	.795
CFES	.861
TGO	.719
CID	.839
LED	.405**
Desired Outcomes	.818

* No Cronbach's Alpha was calculated for Co-creation as it consisted of 1 item.
** LED has a critical value for Cronbach's Alpha.

Table 1 shows all Cronbach's Alpha scores. The items of the 3C model are considered as marginally sufficient. The scale of Collaboration (Col) has a just below .70 reliability. The scale of Lean Education (LED) is considered insufficiently reliable. We will take these findings into account when it comes to drawing conclusions. In general the questionnaire as a whole can be seen to be reliable (.93).

Percentages
To obtain insight in the extent of recognition of the proposed vision of the education ecosystem, we counted the answers in every answer category and calculated the percentages. Figure 2 shows the percentages found for every category of the questionnaire. Positive answer categories (score 4 and 5) and negative answer categories (score 1 and 2) are clustered.

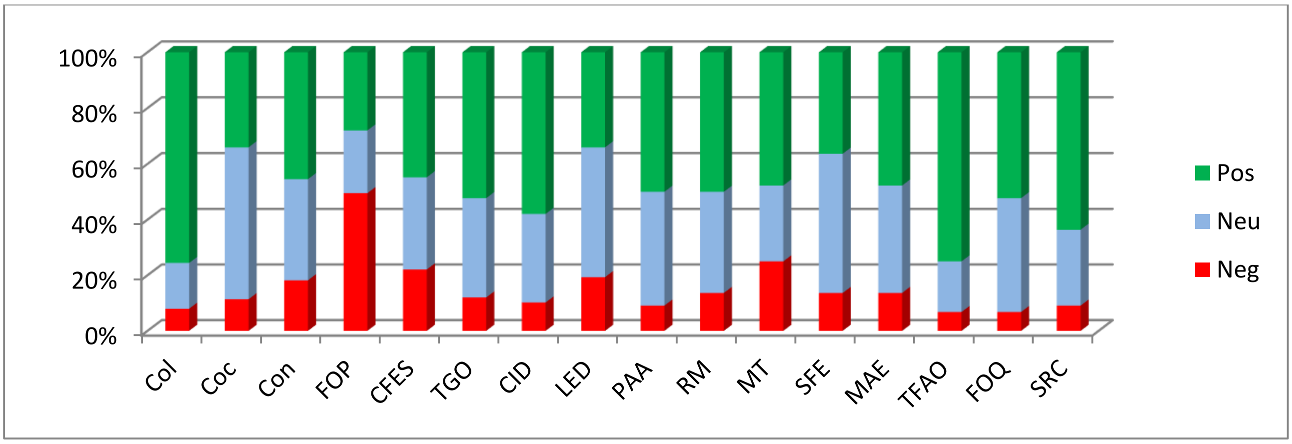

Figure 2. Percentages of all students on education ecosystem questionnaire.

Figure 2 shows that students score high on recognizing Collaboration (Col, 75.6%), Take Full Advantage of Opportunities (TFAO, 75%) and Subjects are Relevant and Challenging (SRC, 63.6%). In addition, the Collaboration statements *"I recognize interdisciplinary teams in working on projects"* and *"I recognize using emerging technologies (like 3D printing)"* have high scores. Students indicated that Focus on Positive (FOP, 77.2%) and Managing Time (MT, 25%) are not recognized in the minors. Students are neutral on recognizing Co-creation (Coc, 54.5%) in the minors.

Mean scores

To obtain insight in the extent of recognition of the proposed vision of the education ecosystem we calculated mean scores and percentages of each of the respondent groups. Figure 3 shows the mean scores of the students on the constructs of the 3C model and Circle of Five.

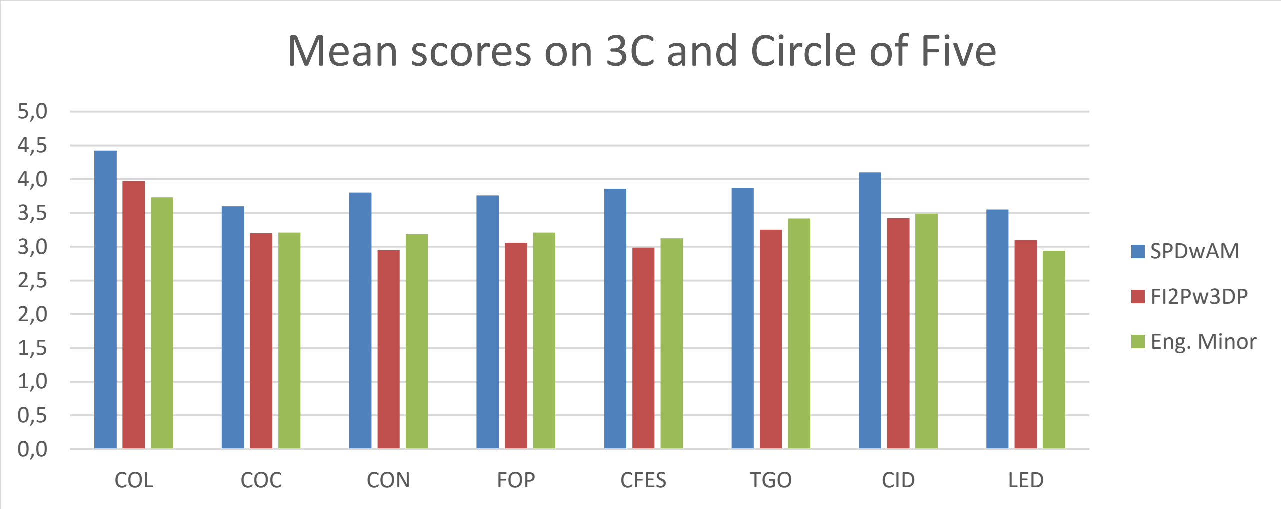

Figure 3. Mean scores on 3D model and Circle of Five.

Figure 3 shows that both SPDwAM and FI2Pw3DP students score high on Collaboration (≥ 4.0). Furthermore, the SPDwAM students also score higher than 4.0 on Cohesion in Development (CID). Finally, the Engineering minor students score ≤ 3.0 on Lean Education (LED).

On the items concerning the Desired Outcomes the following mean scores were found:

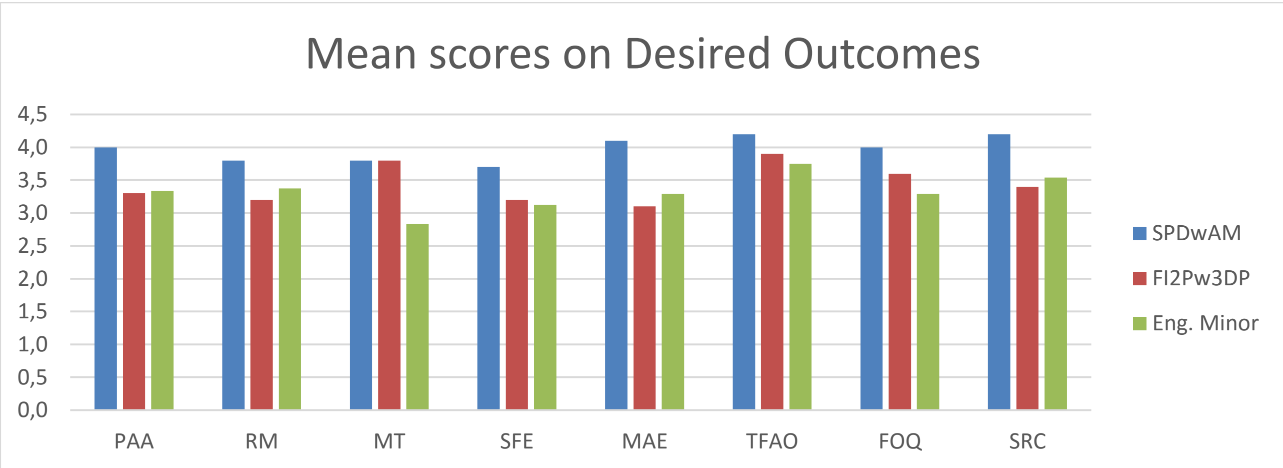

Figure 4. Mean scores on Desired Outcomes.

Figure 4 shows that SPDwAM students score above 4.0 on Pro-Active Attitude (PAA), Meaningful and Actively Engagement (MAE), Take Full Advantage of Opportunities (TFAO), Focus On Quality (FOQ) and Subjects Relevant and Challenging (SRC). Furthermore, the Engineering Minor students score below 3.0 on Managing Time (MT).

3.2 Comparing the groups

A one-way ANOVA was performed for the three groups: SPDwAM, FI2Pw3DP and Engineering Minor. The F-values were calculated to find out if the groups differ on recognizing the 3C Model, Circle of Five, Desired Outcomes and the vision of the education ecosystem.
The critical value for the respondent groups is $F(2,41) = 3.23$. If significant differences were found, a Scheffe post hoc test was performed to distinguish which groups differ from each other.

Table 2. Anova on 3C Model, Circle of Five and Desired Outcome

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
3C Model	Between Groups	16.673	2	8.337	.743	.482
	Within Groups	459.758	41	11.214		
	Total	476.432	43			
Circle of Five	Between Groups	1853.051	2	926.525	5.450	.008*
	Within Groups	6969.858	41	169.997		
	Total	8822.909	43			
Desired Outcomes	Between Groups	197.851	2	98.925	5.617	.007*
	Within Groups	722.058	41	17.611		
	Total	919.909	43			
Vision on Education Ecosystem	Between Groups	3556.673	2	1778.337	6.121	.005*
	Within Groups	11911.758	41	290.531		
	Total	15468.432	43			

Table 2 shows that the respondent groups significantly differ on their overall recognition of the Circle of Five, Desired Outcomes and the vision on the education ecosystem, because the F-value is > 3.23. The Scheffe post-hoc test showed the following significant differences (alpha ≤ 0.05): on Circle of Five a difference between the SPDwAM group and the FI2Pw3DP group (0.022) and a difference between the SPDwAM group and the Engineering Minor Group (0.017) was found. On vision on education ecosystem a difference between the SPDwAM group and the FI2Pw3DP group (0.016) and a difference between the SPDwAM group and the Engineering Minor Group (0.010) was found. On Desired Outcomes the SPDwAM group and the Engineering group differed (0.022).

4 Conclusion

Collaboration and Take Full Advantage of Opportunities are best recognized in our minor program. There seems to be room for improvement left in Lean Education according to the Engineering Minor students, however, the low reliability of the category has to be taken in account. Although we see that the students predominantly recognize the vision of the education ecosystem, we also see a great amount of students are neutral in their answers. A possible explanation could be that the survey has been taken on 25% execution of the minor program.

In general, all groups recognize the vison of the education ecosystem. However groups may differ in the extent of recognizing the educational vision. Although the facilities and the environment for all minor groups are similar, the groups perceive the education ecosystem differently. A likely explanation lies in the human factor of the C.E.T.S. model.

In further research we will explore the human factor on developing, executing and perceiving the education ecosystem.

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