Continuous Research and Development Partnership in Engineering Education

Andreas Probst[1(✉)], Detlef Gerhard[2], Sébastien Bougain[2], and Christian Nigischer[2]

[1] HTL Ried, Ried im Innkreis, Austria
Andreas.Probst@eduhi.at
[2] MIVP Institut, Technische Universitaet Wien, Vienna, Austria

Abstract. In Austria a unique research program the so called Sparkling Science has been introduced by the Federal Ministry of Science, Research and Economy in 2007. Within this program, a research collaboration between Technische Universitaet Wien (TU Wien) and several Austrian Federal Secondary Colleges of Engineering (in Austria called HTL) has been set up. This paper gives an overview about the achievements so far including a survey about the impact to daily engineering education.

Keywords: PLM · CAD · V-model · CAx · Engineering education · Engineering collaboration · MBSE

1 Introduction

Research partnership in engineering between vocational schools and universities is supported by the Austrian Sparkling Science program, which was set up by the Austrian federal ministry of Science, Research and Economy in 2007. The aim of this program is to bring science and schools together. One particular goal is to increase the interest for STEM fields (Science Technology Engineering and Mathematics), because there is a significant lack of engineers in Austria and whole Europe as well. Therefore, in this program pupils and students of any Austrian schools are able to work together with scientists and lecturers from Austrian universities and play an active role in research projects. From 2007 to 2016 there have been 198 research projects started [1].

The purpose of this paper is to give an overview about the current research partnership and projects together with TU Wien and some HTLs, as well as to figure out the amount of influence to engineering education practice. Additionally, the aim is to identify the key factors for a successful cooperation in engineering education benefitting both, university institution and the secondary colleges. This paper will also give an overview about the current Sparkling Science research project "Systems Engineering" conducted by the mentioned partners.

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2 Completed Sparkling Science Projects Between TU Wien and Austrian HTLs

Up to this date two projects have been concluded between TU Wien and Austrian HTLs and one is currently in progress.

2.1 Sparkling Science Project BLUME

Due to increasing complexity of product development in industry, curricula at Austrian HTLs have been adopted since 2006 to meet the changed requirements. Besides developing the ability to work in geographically distributed teams, enhanced software tools had to be introduced to education lessons as well. This was realized in the course of the project BLUME (Basis PDM Lern- und Projekt-Umgebung für ganzheitliche Mechatronische Produktentwicklung in German: means learning and education environment for mechatronic product engineering) particularly introducing the Product Data Management (PDM) system Windchill (PTC) as engineering data management backbone for the involved schools. Since a PDM system has to be configured to meet the user requirements concerning usability and support, it took some efforts from the project team members to customize the software tools in order to suit the requirements of collaboration among pupils and schools. For example, templates for individual projects as well as for classroom projects were created and adapted. Furthermore, special video trainings concerning PDM systematic and for using Windchill were created [2].

2.2 Sparkling Science Project PDM-UP

After introducing the PDM system Windchill and adapting it to the needs of engineering education, a subsequent project called "PDM-UP" (UP – Umweltgerechte Produktentwicklung in German means "Design for Environment – DfE" also referred to as Ecodesign or green design) was started. Main targets were to include DfE approaches in vocational education and provide the required IT tools for performing environmental analyses. Despite mechanical engineering education at Austrian HTLs includes approximately 600 h spread over five years, DfE is not part of the design lectures but is demanded form industry increasingly. Thus, a particular goal of this project was also to train students performing environmental evaluation of their design concepts independent of their CAD system in use.

Therefore, additional adoptions for increased usability like enhanced CAD and PDM templates, CAD libraries within Windchill as well as general system configuration were made. Existing CAD design data with defined parameters in a PDM system was complemented with data from environmental databases containing environmental impact indicators in this case indicator for global warming. Indicators like Global Warming Potential (GWP) or Cumulative Energy Demand (CED) [3] could be determined using the software and alternative approaches could be evaluated.

3 Key Factors for Successful Research and Development Partnership

3.1 TU View

For TU Wien it is important to get in touch with its future students. On one hand the different educational programs and research domains are presented. Students can also visit the university and get in touch with scientists when they come to attend a project's workshop. On the other hand, cooperation should introduce the future important topics to future engineers. The earlier STEM students learn or at least hear about these upcoming topics of an engineer's work the better they will be able to adapt or grasp the functioning of it. Such cooperation aims to optimize the learning process.

A key factor to maintain this cooperation along the project is the established PDM environment based on Windchill. Each project member is able to look at the updated project's calendar and can also download presentations or tutorials needed for the execution of his or her tasks during the project time. Furthermore for researchers at TU Wien it is a good way of shaping educational materials and strengthen teaching skills. Different topics or problems like the complexity of the subject can be highlighted.

3.2 HTL View

There are three main aspects for HTLs to cooperate in research projects with technical universities.

Firstly students of technical colleges get information and knowledge about technical universities. Since there are not enough highly qualified engineers entering the labor market this is very important. Also students are able to get in touch each year with scientific work. Often this is a key factor for them to decide whether to continue education at universities or to begin a job in industry.

Secondly HTL teachers have the opportunity to communicate and exchange ideas with TU researchers about new and upcoming techniques and methods of teaching them. Since HTL teachers have traditionally good contact to industry companies and therefore newest trends in industrial development and production, this is a good enlargement of their experiences. Of course this will have an impact into daily teaching practice as well.

The third aspect is the impact to the curricula at HTLs. Being involved in research projects with new techniques and methods gives the opportunity to introduce these aspects into regular meetings of curricula committee which consists of members of Austrian Federal Ministry of Education as well as teachers of Austrian HTLs.

4 Current Project "Systems Engineering"

The current research project "Systems Engineering" aims to deepen the collaboration between the different technical educational institutions in Austria and extend the designing knowledge for the early stages of the product development process with

systems engineering methods. While the four participating HTLs have their focus on detailed construction design aspects, approaches for dealing with the increasing product complexity on a higher abstraction level already in the early phases of product development are missing in the curricula. Thus, the main objective of this research project is to sensitize teachers and students for the need of approaches like "Model Based Systems Engineering" (MBSE) and provide methodology know-how to overcome the difficulties of complexity and collaboration. Furthermore, TU Wien is able to get feedback about teaching Systems Engineering methods and approaches from teachers and students of the involved HTLs. Pupils at participating vocational schools are directly involved in the research process of adapting general purpose systems engineering methods to product development challenges.

The already mentioned collaboration platform established in previous Sparkling Science projects is used to allow flawless data exchange between all project participants. In order to allow practical MBSE experience with a state-of-the-art software tool, PTC as a project partner provides the modelling tool ATEGO. ATEGO allows the creation of system models using the Systems Modelling Language (SysML), which is a graphical modeling language based on the Unified Modelling Language (UML). As a guideline for the approach of developing complex mechatronic products the V model stated in the VDI 2206 [4] is utilized to learn the basic methodology. Because the students of the HTLs shall not only learn the theory of MBSE, the project follows the learning-by-doing concept exercised during interactive workshops. The practical task of the students is to develop a model of a 3D printer. Therefore a MendelMax 3D printer serves as an illustrative object. A CAD model of the printer is shown in Fig. 1. Parallel to the work of

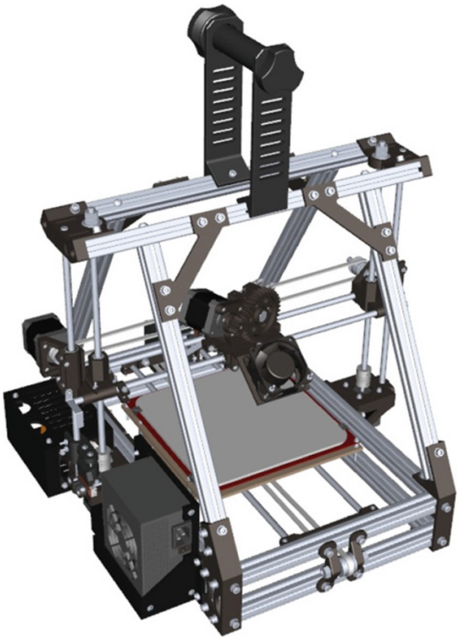

Fig. 1. CAD model of the MendelMax 3D printer

the involved HTLs a SysML model and various improvements are made in the course of bachelor theses at TU Wien. Furthermore, step-by-step tutorials for the usage of ATEGO and the design methodology were generated. At the end of the project, the solutions of the schools and the students of TU Wien will be compared and discussed. There also will be an evaluation of the learning experience and benefits created for all project participants. Additional information about the project "Systems Engineering" can be found in [5].

5 Survey About Research and Development Partnership

5.1 Research Question

To evaluate the main research question "Do the projects of the Sparkling Science program influence the teaching practice in engineering education at Austrian HTLs and the involved persons perception of the program itself?" a survey was conducted in spring 2016. The survey addresses points like knowledge about tasks of current and past research programs, as well as importance of joint research programs over different groups.

5.2 Survey Groups

The first two groups (A + B) include current and former HTL students, the next group (C) contains HTL teachers and the last group (D) includes professors and staff from TU Wien. For these four groups the decision is taken to differentiate between people who have attended and those who have not attended any Sparkling science projects. So there is always a reference group who has only indirect contact to the program through classmates or colleagues. All groups with persons who have participated in research projects contain the number "1" in their group names and all groups with non-participants have the number "2" in their group names. Table 1 gives a brief overview about the different groups in the survey.

Table 1. Overview different survey groups

Overview different survey groups	
Group	Group description
A1	Students who have attended Sparkling Science programs
A2	Students who have never attended Sparkling Science programs
B1	Former Students who have attended Sparkling Science programs
B2	Former Students who have never attended Sparkling Science programs
C1	HTL Teachers who have attended Sparkling Science programs
C2	HTL Teachers who have never attended Sparkling Science programs
D1	TU Professors or staff who have attended Sparkling Science programs
D2	TU Professors or staff who have never attended Sparkling Science programs

Figure 2 shows a summary of 34 answers from students (A1 + A2) and former students (B1 + B2), 27 answers from HTL teachers (C1 + C2) and 7 answers from TU

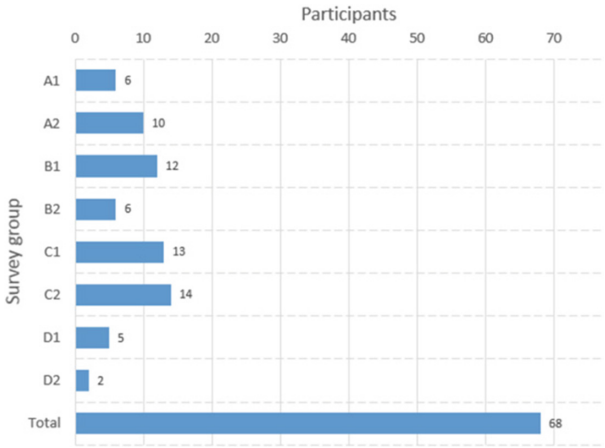

Fig. 2. Survey participants over different survey groups

Table 2. Overview survey questions

Q-Nr.	Survey question
Q1	Gender question
Q2	Which survey group A to F describes your status converning the Sparkling Science programs
Q3	Do you know the Sparkling Science program?
Q4	Do you know the Sparkling Science project “BLUME” with its target to introduce PLM to Austrian HTL?
Q5	Do you know the Sparkling Science project “PDM-UP” with its target to introduce PLM to Austrian HTL in combination with design for environment?
Q6	Do you know something about the tasks and functionality of a PDM system?
Q7	If yes, can you please give some task examples of a PDM system.
Q8	Do you use a PDM system within your design work?
Q9	Do you know the Sparkling Science project “Systems Engineering” with its focus on Model Based Systems Engineering?
Q10	Do you know about the tasks of the reasearch project Systems Engineering?
Q11	If yes, can you please give some task examples of the reasearch project Systems Engineering.
Q12	How impotant do you see the implementation and usage of Systems Engineering within education at Austrian HTL?
Q13	For which tasks or fields within education at Austrian HTL do you recommend Systems Engineering methods?
Q14	Do you see the influence of Sparkling Science research projects general in teaching at Austrian HTL?
Q15	If yes, which criteria could you identify therefore?
Q16	How do you rate the importance of Sparkling Science research projects for the development of teaching content at Austrian HTL?
Q17	How do you rate the importance of collaboration of technical universities and Austrian HTL in Sparkling Science research projects in general?
Q18	Should cooperation within research projects between technical universities, universities of applied sciences and Austrian HTL generally be extended?

professors or TU staff (D1 + D2). Concerning gender aspects there is a distribution of 8.3% (absolute 6) female answers and 91.7% (absolute 66) male answers. All female answers were from students or former students. The average percentage of female students at Austrian HTLs is 16.67% [6].

A number of only 12 responses from former students who have attended recent research programs as well as a number of 6 regular students who are attending the current research program show the difficulty to motivate students to attend such a survey.

5.3 Survey Questionnaire

Though the survey has been done in German language, Table 2 gives a short overview about the asked questions in English.

5.4 Survey Results

Before the first project "BLUME" was conducted, none of the Austrian HTLs touched the topic of product data management in their education. Therefore, introducing this emerging technology was one of the most visible results of the project. More than two-third of the respondents stated that they know the basic concepts and functionalities of a PDM system. Especially the proportion of positive answers from the HTL teachers (C1, C2), even if they did not participate in any Sparkling Science project, is comparatively large. Figure 3 illustrates the results of question 6 in detail.

Question 7 asks for task examples and functionalities of a PDM system. The results show that 87% of people, who stated that they know what a PDM system is, really can

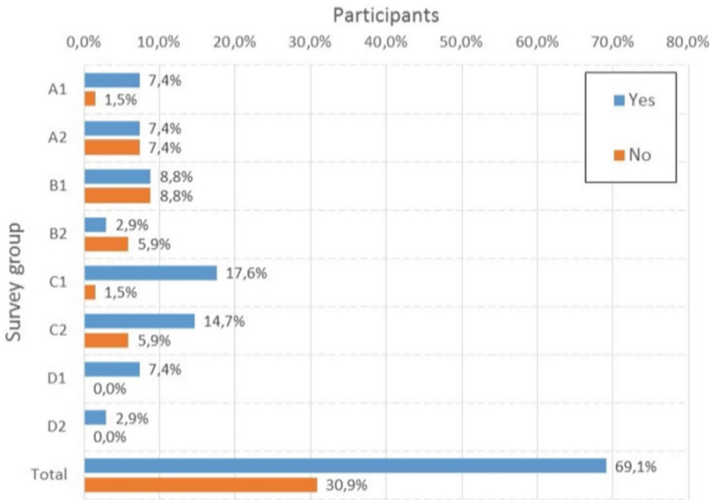

Fig. 3. Question 6 survey results

name and describe various core tasks and functionalities of PDM systems. Strangely people who were not able to give an answer to this question belong to the former students respectively the HTL teachers group who already participated in Sparkling Science projects (B1, C1). The complexity of tasks a PDM system can do may be the main reason for them to not be able to give a short answer. Some even say that nobody could exactly know what a PDM system can do. Further analyses of the survey results reveal that 27% of all respondents, mainly students and teachers from HTLs, not only know core functionalities of a PDM system, but also practically use a PDM system for their constructions. This outcome is quite encouraging to pursue the effort of bringing knowledge about PDM systems to the Austrian HTLs.

Independent of the knowledge level concerning PDM systems, 36.8% of all survey participants actually use a PDM system within their design work. Only the groups A1 and C1, which contain the answers of Sparkling Science project attending HTL students and teachers, have a higher percentage of PDM users than non-users. This can be an indication that the Sparkling Science projects successfully started the introduction of PDM systems in the HTLs. Detailed numbers to question 8 can be found in Fig. 4.

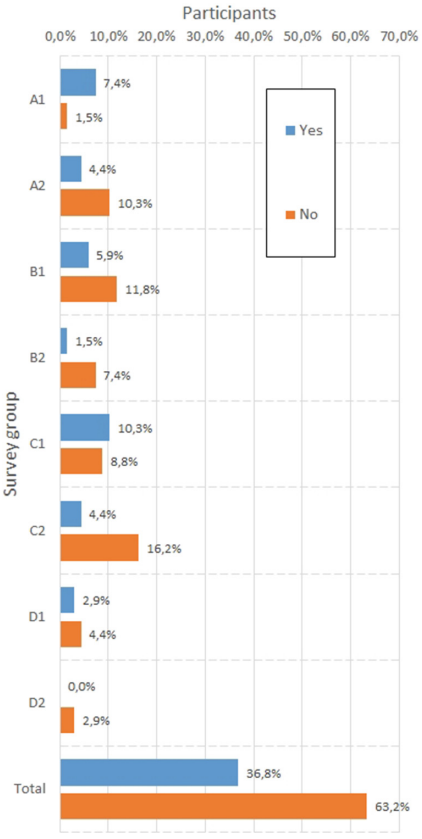

Fig. 4. Question 8 survey results

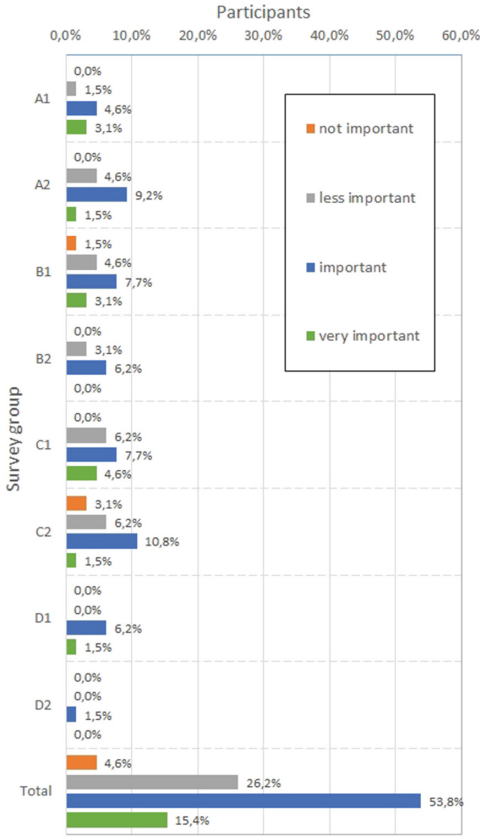

Fig. 5. Question 12 survey results

Asked for their opinion concerning the importance of implementing Systems Engineering into the curricula of Austrian HTL, 69.2% of the survey participants stated that this subject is at least important to them. Only 4.6% think Systems Engineering has no significant impact to education quality of the HTLs. Detailed results can be found in Fig. 5.

Question 13 asks for the fields where Systems Engineering can be advantageous for the students (multiple answers possible). More than 35% of all answers attest students with Systems Engineering increased chances for their career entry. Other important points are the technical understanding of complex products and the ability for interdisciplinary teamwork. Details are illustrated in Fig. 6.

45.4% of the survey participants think that Sparkling Science projects do not have a significant impact to teaching in Austrian HTLs. Only 29.7% state that Sparkling Science projects have a noticeable influence to the education at HTLs. Mentionable hereby is that HTL teachers who attended in a Sparkling Science project already have the largest proportion of answers that attest at least noticeable impact. Figure 7 shows the detailed evaluation.

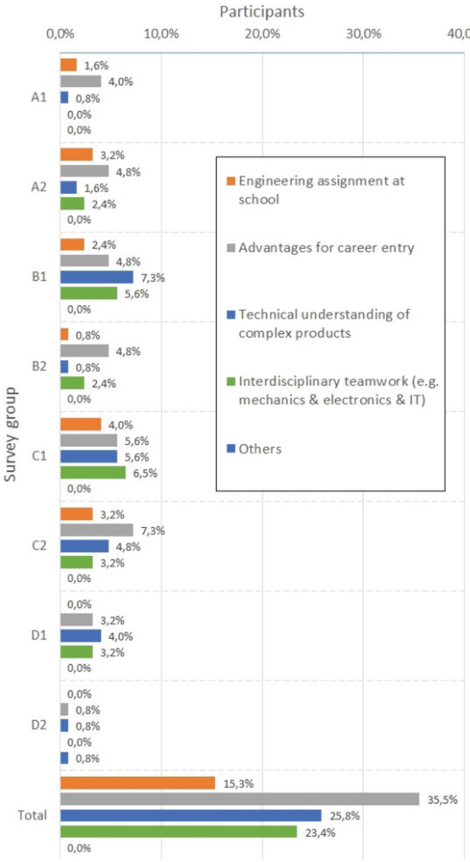

Fig. 6. Question 13 survey results

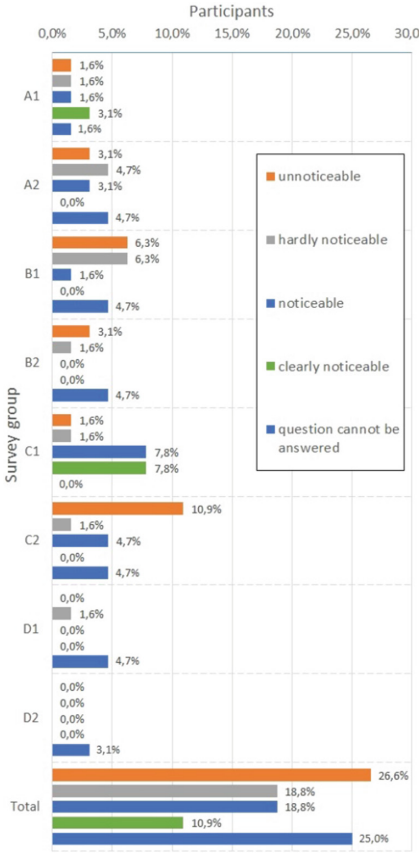

Fig. 7. Question 14 survey results

In contrast to the results of question 14, 65.4% of all survey participants rate Sparkling Science projects as at least important for the development of new teaching content for Austrian HTLs. Only 6.3% think the Sparkling Science program is not important for the education in HTLs. Details are illustrated in Fig. 8.

83.1% of all survey participants rate the cooperation between TU Wien and Austrian HTLs within the Sparkling Science program as important or very important. Especially students and teachers which have already participated in a Sparkling Science project (groups A1 and C1) are convinced of the university-school cooperation. Detailed numbers can be found in Fig. 9.

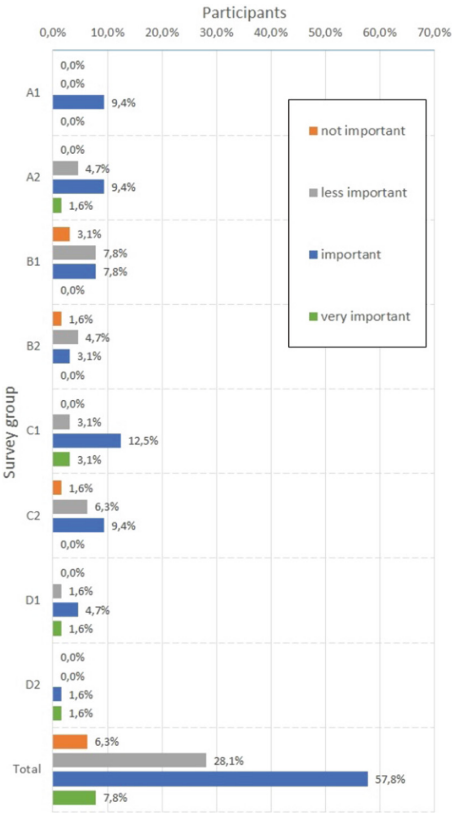

Fig. 8. Question 16 survey results

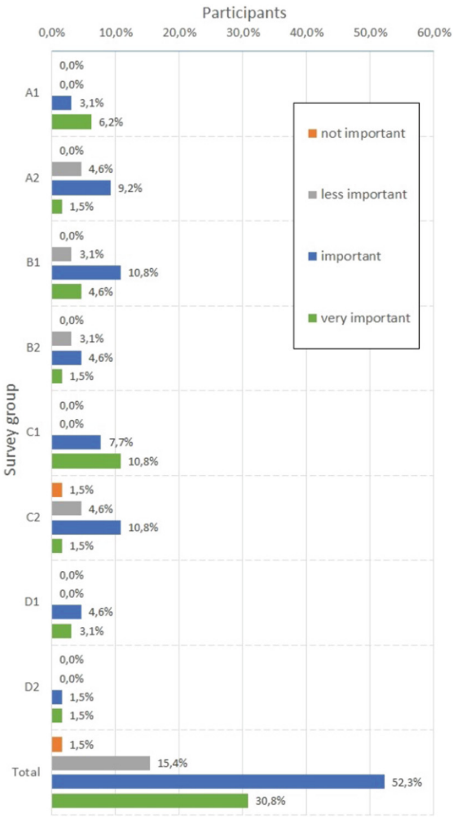

Fig. 9. Question 17 survey results

5.5 Interpretation

Concerning the project “Systems Engineering”, people were asked if they know about it and if they can explain the main ideas, concepts, and tool approaches towards systems engineering. As the results shown below in Fig. 10, it is quite clear that people who have participated in a project better know what systems engineering is. Yet people

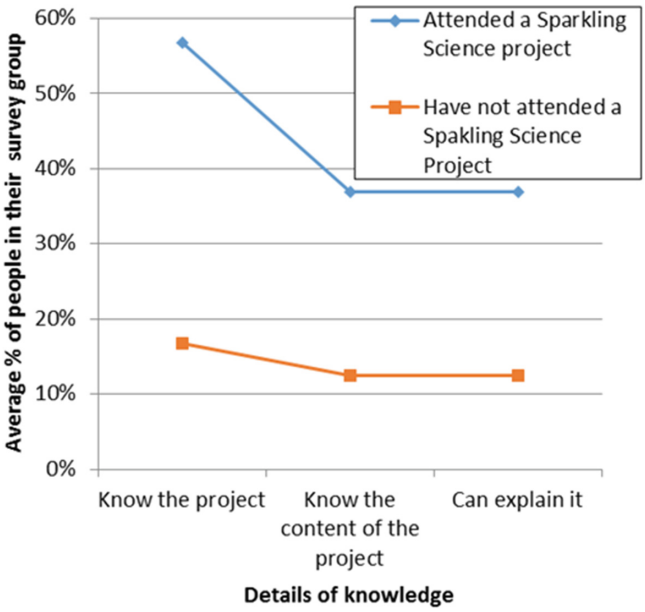

Fig. 10. Different level of knowledge about the project "Systems-Engineering"

who have not participated know less about the concepts of systems engineering. This fact confirms that the project successfully builds knowledge of MBSE in the HTLs. Another interesting point for future researches could be the investigation of success and domains of studies of the people who participated in Sparkling Science projects.

Concerning the open question about PDM systems, an analysis was made about the written answers. In order to keep the grading system simple, people who mentioned the way data is managed (workflow, change management, configuration, etc.) received one point, people who mentioned collaboration aspects (roles, access management, etc.) made possible through a PDM system also received one point. The maximum is 2 points for mentioning both aspects, which indicates strong knowledge about PDM systems, while the minimum of 0 point is associated with weak knowledge. 1 point is interpreted as average knowledge level. By analysing the data structured with the introduced grading system, it seems that people who have attended any Sparkling Science projects are more familiar with PDM systems than non-participants. Almost 38% of the project participants were able to achieve both points, while only 22% of the non-participants managed to reach 2 points. These results show the success of bringing knowledge about PDM systems to the HTLs. Figure 11 illustrates the outcome using the 2 point grading system with the correlated knowledge level.

Considering the knowledge of PDM in the separate survey groups, Fig. 12 reveals that students who are participating in a Sparkling Science project (A1) know a lot more about PDM systems than the ones who don't (A2). But it also shows that over time the students tend to forget about it (B1), or that the teaching got better than it was at the beginning of the program. Further studies will have to be made in order to answer this question.

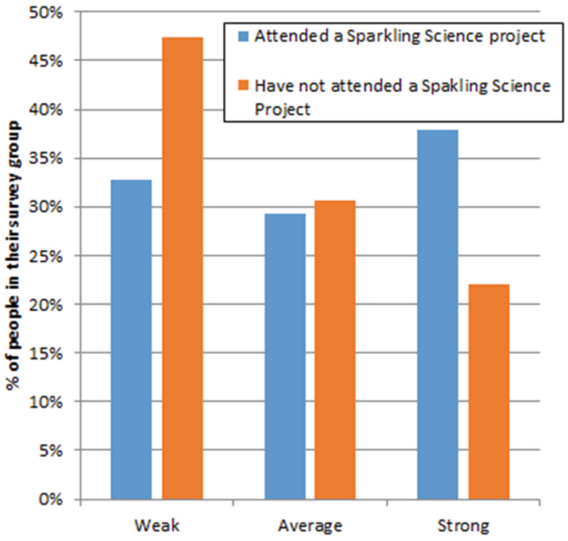

Fig. 11. Different level of knowledge about PDM

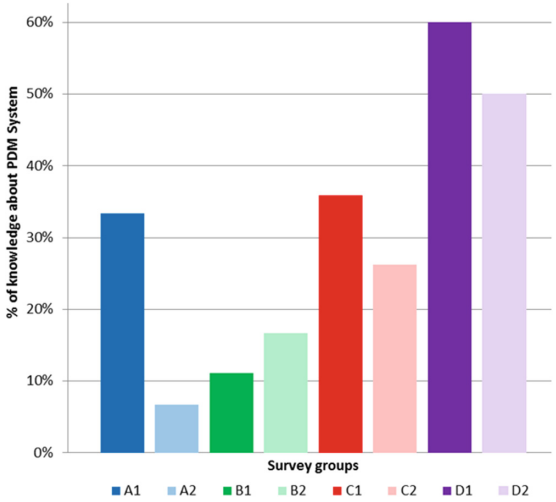

Fig. 12. Distribution of the knowledge about PDM systems over the survey groups

The main influences of the Sparkling Science program were also investigated. According to the survey answers, which are categorized in Fig. 13, the main influence comes from the practical use of PDM systems and the collaboration experience. These two points are followed by the influence of Sparkling Science to the content of teaching materials and finally the influence to different theses that are made through the year. Students are hence learning what a PDM system is, they also use it in order to

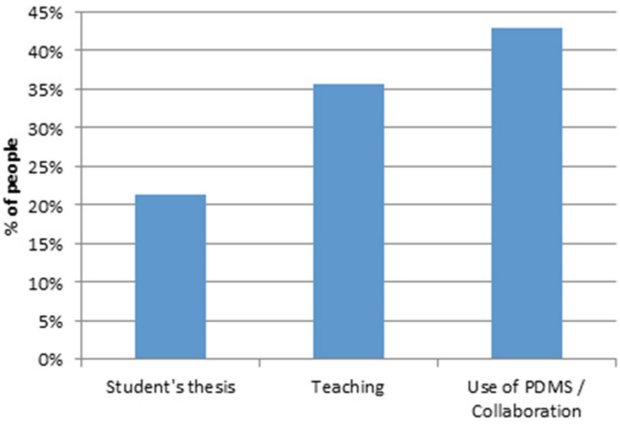

Fig. 13. Influences of the Sparkling Science program

learning-by-doing, and finally if they want a deeper understanding they manage to write a thesis about it. Those influences are very encouraging to pursue this collaboration.

6 Conclusion and Outlook

It seems absolutely necessary to evaluate the knowledge about project topics of all the participants at the beginning of upcoming projects. Additionally an evaluation after finishing the research project to get information about the change of knowledge compared to the project start is necessary too. Evaluation during the running project is an option too. All these information will give enhanced feedback about the performance of upcoming projects. Doing a survey earlier in the research project will increase the number of answers from students who work on the project.

As people were facing difficulties with CAD systems 15 years ago, they are facing problems handling PDM systems today. Model Based Systems Engineering with ATEGO is in an early stage. Feedback during the project highlights the complexity of handling such a new software. This is why some improvements concerning workflow, look and feel as well as interfaces to other programs should be introduced.

Overall, the results from the survey conducted in spring 2016 are a big encouragement to continue the effort of cooperation between HTLs and TU Wien that started nine years ago in 2007. Nevertheless, as already stated above, it would be interesting to perform further investigation in order to know if the introduced projects create additional value over time for the participants.

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