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Increasing student confidence and motivation in a project-based Machine Construction and Mechatronics course

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Abstract

This paper describes an *exercise project* implemented in a 7th semester mechatronics course for mechanical engineers. The projects intention is to teach technical know-how, theoretical understanding, practical experience and to increase confidence in the students. This is achieved by encouraging exploration, practical work and to let the students' experience achievement in a new subject early in the semester. The project spanned over 4 four weeks and the task was to build an Arduino based robot that reacts on input from minimum two sensors.

Previous years' exercise routine has been a teacher driven activity that left little creative freedom for the students. However, by adopting ideas from both project-based learning (PBL) and design thinking (DT) the focus has changed. Creative confidence or creative self-efficacy is one of the most important aspects for the students to develop, along with a good understanding of the theory. As an experiment, we incorporated these elements in the exercise routine of the course. The intent was to increase the students' confidence in the theoretical elements of the course and in their abilities to solve relevant problems.

There were 71 students in the course with a gender distribution of 59 male and 12 female. Measurements were done using a questionnaire (n=43) answered just after the project was finished, 36 male and 7 female. The results presented in this paper are based on dichotomous items from the questionnaire. The descriptive results show an increase of motivation for learning mechatronics (88.4%), increased confidence in translating theory to practice (79.1%) and high satisfaction on individual performance in the project (82.9%). This indicates that the project was successful. The complete dataset and the exercise project is discussed further in the full paper.

Keywords: Engineering education, mechatronics education, confidence, motivation

1 Introduction

We implemented an exercise project in a 7th semester mechatronics course for mechanical engineers, equivalent to a first year graduate level, with an emphasis on intrinsic motivation and problem driven learning. We describe the implemented project, and present an analysis of the project based on a simple questionnaire, and two open questions. We show examples of project outcome, and discuss the effectiveness of the exercise project as a learning activity in terms of student satisfaction, motivation, and confidence. The basis for comparison is previous years' weekly tutorial-based exercise routine. No data is available for the previously used exercise routine.

This paper contributes with an educational task for practical mechatronics education, and an analysis of this educational activity in light of enhancing student confidence and motivation. Our analysis shows that the exercise routine gives students a feeling of increased confidence and motivation for the topic. We also see that the act of making is highly motivating, along with the sensation of learning throughout the project. A few other papers have been published showcasing mechatronics education routines based on projects aiming to increase motivation and confidence. (Analytis, Sadler, & Cutcosky, 2015; Grover, Krishnan, Shoup, & Khanbaghi, 2014) What this paper does differently is to examine the constructs that affect the students' motivation.

2 Theoretical background and method

Our ultimate goal is to educate engineering students to become excellent design engineers, a branch of engineering that in its nature is creative and requires constant reflection and evaluation of ideas and concepts:

> *Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints.(Dym, Agogino, Eris, Frey, & Leifer, 2005)*

Project based learning (PBL) has for several years been an educational method used to give students work-like experiences (Dutson, Todd, Magleby, & Sorensen, 1997), (Frank, Lavy, & Elata, 2003) and is shown to increase students work-readiness (Jollands, Jolly, & Molyneaux, 2012), (Lehmann, Christensen, Du, & Thrane, 2008) and professionalism (Thomas, 2000). Criticism of PBL and other minimal guidance learning methodologies highlight that these methods are less effective at teaching core elements of a subject in terms of its facts, laws, principles, and theories than their traditional counterparts. (Kirschner, Sweller, & Clark, 2006). The facts, laws, principles, and theories that make up a discipline can be seen as individual skills (Litzinger, Lattuca, Hadgraft, & Newstetter, 2011), referred to as *component skills* by Ambrose, Bridges, DiPietro, Lovett, & Norman (2010). For a design engineer to be successful, the component skills needs to be applied to complex problems, a more difficult skill that requires practice. *„Thus, to help students proceed along their pathway to expert performance, the curriculum must provide multiple opportunities for them to practice their skills on authentic tasks that require the integrated application of various knowledge and skills" (Litzinger et al., 2011).*

Another element found to have a large impact on design engineers is confidence. (Davies, 2000), (Laws, 2002). Described as self-efficacy by Bandura (1997), a persons belief in his/her capability affects a situations outcome (Beghetto, 2006). Especially creative confidence is seen as an important personal treat, which led to the introduction of design thinking (DT) (Rauth, Köppen, Jobst, & Meinel, 2010). DT along with PBL has provided a basis for designing the open-ended project-based exercise project presented in this paper. The project does not claim to be either a clear-cut PBL activity, as it has no grounding in any *real world problems*, or a design thinking activity. Rather, it is aimed at training application skills relevant for an engineering designer within the theoretical realm of mechatronics; problem solving and application of theory to practice. The task is also intended to enhance student confidence by verifying the applied theory through tangible confirmation in the shape of a functioning robot.

The analysis in this paper does not attempt to define any theory or hypothesis, it is a descriptive evaluation of the project aiming to highlight relevant constructs for the case. With further research and case analysis, Eisenhardt‘s (1989) methods may lead us towards new theories.

3 The exercise project

In order to challenge the students to challenge themselves, and to provide an opportunity for practicing the lectured theory. An exercise routine in the form of a project was given to the class. During this project, the students would build small functioning robots implementing sensorial input and output to motors, lights etc. The learning activity was placed early in the semester, week two (2), and lasted for five (5) weeks. The course spans over fifteen (15) weeks in total. The students were divided into two (2) person groups, where the grouping was done by the students themselves. Due to an odd number of students in the class, and some late course registrations, we ended up with a few three (3) person groups as well. The reason for having small groups in this exercise project, was to increase the chance of good learning outcome for every student, while at the same time providing a partner to lean on if the task got too challenging. In addition to the project text, each group was given a *project kit* consisting of an Arduino Uno microcontroller, a small 9g servomotor, two geared DC motors from DAGU robotics and a USB cable to serve as a minimal basis on which to build further. See figure 1.

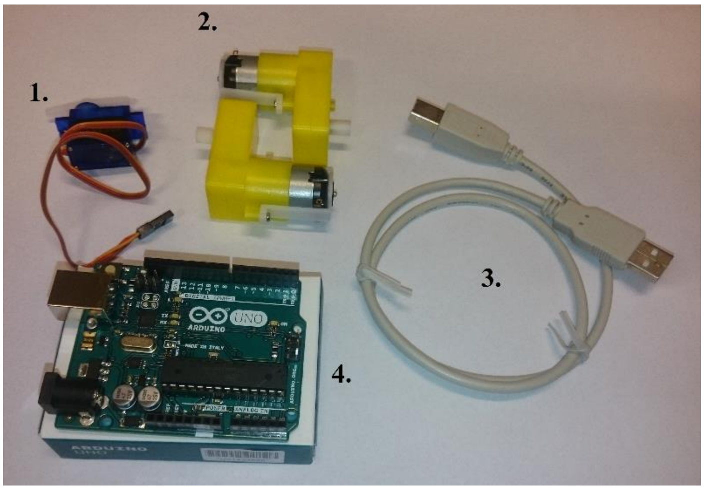

Figure 1. The contents of the *project kit* given to each student group. 1 – Servomotor, 2 – Geared DC motors, 3 – USB cable, and 4 – Arduino Uno microcontroller board.

Additional components such as sensors, resistors, wires, breadboards, workstations with soldering irons etc. were accessible in the dedicated mechatronics lab at the institute. The students had access to this lab during normal working hours, Monday to Friday 08:00-16:00, throughout the whole course period. Available written material for this project consisted of a compendium developed for the course, which gives an introduction to programming C and tutorials on Arduino including descriptions of components and circuitry. Students are also encouraged to use the internet to find information on components and to solve problems that occur. The first four (4) Fridays of the exercise project, there were two (2) student assistants available for consultation. On the fifth Friday, the students presented their finished robots at an open exposition where institute staff and students were invited to inspect and play with the resulting robots. Final inspections and approval of the project was done during this exposition. The project result was not graded, and did not count towards the final grade in the course. Although it was mandatory to finish and get the robot approved in order to qualify for a grade in the course.

3.1 Project span

The project assignment text was written in such a way that it should set some simple boundary conditions for the students and at the same time leave the solution space as open as possible. To give the reader of this paper as much insight as possible in the exercise project, the assignment text is repeated in full here:

> *Design and build a fun little robot that reacts to its environments and acts on it in some way. The robot has to take input from (at least) two sensors, and react using the available actuators.*
>
> *The robot is to read the sensor input and decide what to do next, i.e. the robot should take decisions based on the sensor input and change operation state accordingly.*
>
> *You are free to decide how your robot should be designed, and what it should do. This small project is meant to be fun, we therefore recommend a little playfulness. Also, don't plan on anything to elaborate, you must finish the build you have planned.*

In addition to the text above, the assignment handout specified available resources and clarified the project requirements. The robot needs to *use (at least) two different types of sensors*, *be movable by one person* and *work as intended in a stable fashion*. The two last requirements are included to stress the importance of setting the ambition level somewhere that is achievable within the span of the project timeline.

3.2 Project output – a series of robots

From day one of the exercise project period, there were activity in the lab with students working through tutorials or testing sensors and actuators. The activity level remained steadily high throughout the whole exercise project period, which created a large variation of robots. See figure 2 for a representation of the robots produced. The picture is quite chaotic, but at the same time it shows off the students' productivity. As a contrast to many engineering courses, this course offers an opportunity for some pure *maker* enthusiasm.

The variation in robotic concepts that were built was surprising. Among the different robots we have a; wall-avoider, guard dog, animated traffic light, vacuum cleaner, color sorter, games, stalkers and an automated fire extinguisher turret.

There was undoubtedly a variance in the quality and ambition level between the different robots. This is unsurprising considering the different backgrounds of the students, where some had previous knowledge regarding mechatronics systems and others had none. Every team did however produce a functioning robot, regardless of previous experience.

Figure 2. The resulting creations at the project period's end. Large variation in themes, concepts and ambition level.

Two examples of robots with either higher ambition level, build quality or both are shown in figure 3. The "Bender" robot has a higher electronics difficulty level than most of the other robots with the implementation of separate microphone and speaker amplification circuits and the use of interrupt functionality in the code. When activated, the robot plays a melody and starts moving around the room in a random fashion. It can be interrupted either by bumping into something or by a sharp sound. After either interrupt, the robot plays another melody and makes a bow after the show. If it bumped into something, it backs away before continuing.

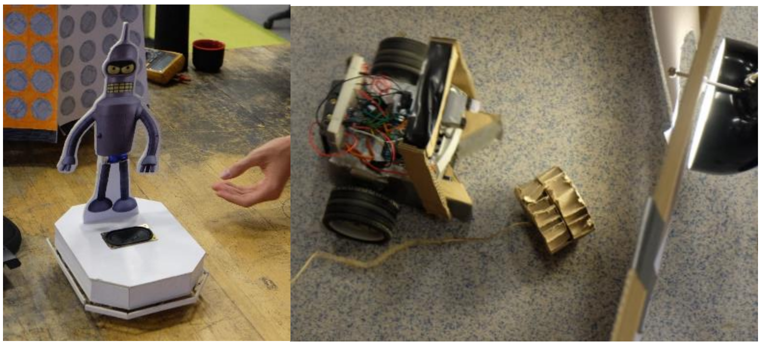

Figure 3. To the left, "Bender", has incorporated a speaker and microphone with amplifier circuits and interrupt bumpers along three sides. To the right, "the Cleaner", is returning a puck to its place next to the white wall in a crate.

The second example, "the Cleaner", shows a high ambition level in terms of getting a detection, decision and navigation algorithm to work. The robot moves around in a confined space containing various objects. When it encounters one of these objects, it grabs onto it and brings it back to one specific side of the space. The *home* area is marked by a white wall with a desktop lamp as shown in figure 3.

3.3 Project costs

A practical learning activity like this does however require resources. With 71 students, our budget allows us to hire two student assistants for 100 hours each. Their responsibility is to coach the student groups throughout the semester. Our mechatronics lab has received investments the last year in the range of 10.000USD. These funds has added both newer infrastructure and a selection of electronics components such as sensors, Arduinos and simple actuators. Some of these components may be damaged or destroyed during the project, adding to the yearly course expenses. A yearly budget for replacing broken parts and components in the lab is estimated to be roughly between 500 – 1000USD, given a consistent number of participants.

4 Findings on motivation and confidence

In order to quantify the experience of this exercise project, the students were asked to answer two questionnaires, one before project start and one just after the project ended. In this paper, we look at a selection of questions from the second questionnaire, given just after the project ended. Results from eight (8) dichotomous yes/no questions, one (1) question with an additional neutral category and two open questions are presented and analysed (n = 43). The closed questions are related to satisfaction, confidence, and motivation for mechatronics and the project. The open questions ask about the most motivating and difficult aspects of the project. These aspects are further referred to as *drivers* and *barriers* respectively. The intention of this analysis is to evaluate the exercise project, to see the students' opinions of the exercise project and attempt to see what they learned from it. The questionnaire was made using Google Form, and distributed to the class via a hyperlink during normal lecturing hours. Results are shown in table 1.

4.1 Closed questions

The questions and answers shown in table 1 are categorized into *confidence*, *motivation* and *satisfaction*. Studying table 1, we see that many students report a high level of confidence and motivational increase related to the exercise project. The same applies for student satisfaction. Looking at the confidence related questions; the data suggests that programming is the most challenging aspect with the project, and we see that both confidence and motivation related to electronics is among the least favourable topics. The motivational aspect of learning mechatronics has been given the highest score. As the term "mechatronics" can be rather subjective in terms of what students associates with it, we believe the result can be seen as a wish for "more of this". Where "this" refers to content similar to what the students experienced in the exercise project. Looking at the satisfaction measurements, we see that the feedback is generally high. We believe there might be a relation between student satisfaction, how much they enjoyed the project, and the motivation they showed while working on it. If we also take the relatively high confidence scores into account, student engagement can be understood through Pintrich's (2003) research on capability as a motivational factor.

From table 1, we see that programming and electronics come out as the lowest scoring items. As our class mainly consists of mechanical engineering students, an explanation can be that they have very limited experience with both electronics and programming. Whereas mechatronics at least contains an element of mechanics, something that is familiar. Another possible explanation for why electronics gets low scores may be the student-cultural differences that tend to emerge between electronics and mechanical engineers, creating a bias against electronics among the mechanical students.

Table 1. Questionnaire results (n=43), valid percentage is shown in parenthesis.

Question	Yes	No	Invalid	Total
Confidence				
Did solving the challenge increase your confidence in programming?	31 (72.1)	12 (27.9)	0	43
Did solving the challenge increase your confidence in translating theoretical principles to practice?	34 (79.1)	9 (20.9)	0	43
Did solving the challenge increase your confidence in solving electronics challenges?	33 (76.7)	10 (23.3)	0	43
Motivation				
Has completing the challenge increased your motivation for learning mechatronics?	38 (88.4)	5 (11.6)	0	43
Did the challenge increase your motivation to learn programming?	34 (79.1)	9 (20.9)	0	43
Did the challenge increase your motivation to learn electronics?	33 (78.6)	9 (21.4)	1	43
Satisfaction				
Do you feel satisfied with your learning outcome from the challenge?	36 (85.7)	6 (14.3)	1	43
Do you feel satisfied with your achievement in the challenge?	34 (82.9)	7 (17.1)	2	43
	Yes	**It was OK**	**No**	**Total**
Did you like working on the exercise project?	37 (86.0)	4 (9.3)	2 (4.7)	43

4.2 Open questions

Trying to uncover where the pain-points were and what the students found motivating gives an insight in their attitude towards the problem and the course as well as aspects of the activity that might need change. The two lists of replies were imported to NVivo, a text analysis tool used for free body text. Using NVivo, a word frequency count was run on both lists separately looking for the ten (10) most used words, accounting for synonyms. The results are visualized as word clouds in figures 4 and 5 where the word size is proportional to the number of times the word is used by the respondents. What we look for in the word frequency count, is repetition of words that describe or are related to the project in some way.

We see a variation in the terms used to describe motivational drivers; they are all related to either what the project had the students do, or what they felt about the project. There seems to be a heavy emphasis on *make* and *learning* as motivational drivers in this project. We note that *programming* and *Arduino* appears among both the drivers and the barriers. *Programming* is even a dominant barrier aspect. We see the words *working* and *work* among drivers and barriers respectively, these words are not seen as synonyms. *Working* is seen as the action of achieving functionality, getting something to work. Whereas *work* is seen as the task of having something to do. In our case, the students most likely experienced the challenge as being labour intensive. Aside from *programming*, there are fewer dominant elements among the barriers than among the drivers.

In order to give the data any meaning, we need to look for connections between the words, not only the words themselves. Only then do they become sentences. Among the drivers, we find *make*, *practical*, *working* and *experience*. The students have experienced making something practical, and they got it to work. Experiencing this combination of activities is associated with what Laws (2002) found to be essential in order to develop self-efficacy within a profession such as engineering design. Another prominent driver is *learning*, which indicates that the students both felt they learned from the project, and that they found this learning experience to be motivating. Both findings are encouraging for the author and indicate that the exercise project is doing something right.

Figure 4. The ten (10) most frequent words used to describe motivating aspects of the exercise project. Motivational *drivers* for the students.

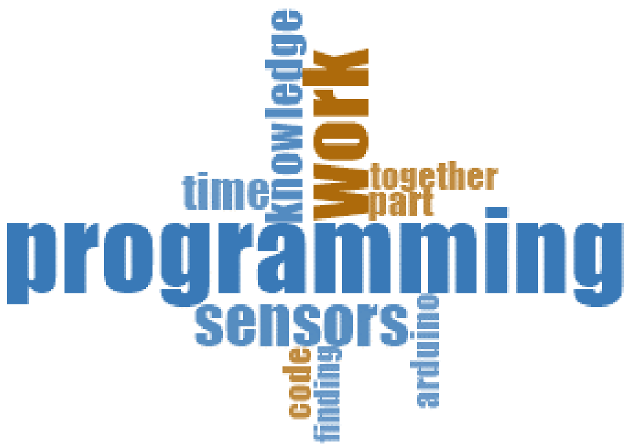

Figure 5. The ten (10) most frequent words used to describe difficult aspects of the exercise project. Motivational *barriers* for the students.

For a group mostly consisting of mechanical engineering students, it appears that the most prominent barrier is *programming*. An item that seems to create both motivation and frustration. The presence of the key elements *programming* and *Arduino* among both barriers and drivers, indicate that educators should not blindly attempt to remove any concepts students struggle with or are frustrated by. In overcoming these barriers, the students appear to come out of the experience with increased motivation. Looking at the barriers as a whole, there are parallels between this project and projects from other practical mechatronics/microcontroller learning activities (Analytis et al., 2015). Difficult aspects in both our, and Analytis' project are related to issues such as programming, available time, hardware, and a feeling of insufficient tutoring. The issue of lacking sensors and other hardware was brought up as frustrating by some and motivating by others. The frustration was grounded in a feeling of not being able to realise plans, while the motivational factor came from a satisfaction of adapting and solving challenges. It would be interesting to see research on whether the different attitudes in students from these two groups are based on differences in confidence levels, motivational levels or other prerequisites.

5 Summary and concluding remarks

Our first observation as the exercise project got started was the immediate increase in activity among the students. Compared to previous years, the activity level was higher among the whole student group. The weekly task-based routine predating the presented project, usually resulted in large differences in effort between those who understood it and those who struggled. In the presented exercise project, students took advantage of the opportunity to scale the ambition level of their own challenge based on their previous knowledge level. The resulting robots shown in figures 2 and 3 show that freedom to take responsibility and an engaging task results in well-regulated difficulty levels and high student persistence. Finding a task that manages to motivate and inspire the student seems to result in an increased amount of work hours put in by both excelling and struggling students. Our data indicates that the project presented here was both motivating and engaging. We also see an indication that the exercise project resulted in an increased confidence among the students.

5.1 Findings

Through organizing an exercise project and analyzing it, we have reached some recommendations for educators organizing mechatronics projects that aim at training students' practical understanding and confidence in applying theory to practice. *Firstly*; students need to build. The experience of creating something that works has been shown to be a strong motivational driver. *Secondly*; students should be allowed to strongly influence the project themselves. As this also seems to benefit the students' motivation and persistence on the task. *Thirdly*; the project task needs to be clearly framed within the course curriculum. The task should also be defined such that the students are asked to *solve this problem*, rather than being told to *do this job*. *Lastly*; teaching staff should act as mentors, asking the constructive questions rather than instructing.

We propose that in order to inspire high motivation and engagement among students in mechatronics courses, the tasks provided should offer freedom to define the ambition level, the opportunity to build something and to be able to finish a project early on in the course. Although there is a cost associated with organising a course with a focus on practical work, we believe the investment is valuable considering the learning outcome for the students. In engineering education, making something reinforces the belief that you can. It is worth the effort to include practical work in order to implement theory in practice.

Further research on the topic should include; expanding the amount of cases, more in-depth statistical examinations of confidence and motivation variables, and identifying other important constructs related to engineering education. Further data gathering from projects should also examine project output to a higher degree in order to better understand the impact of the confidence and motivational parameters.

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