SELF-DIRECTED LEARNING IN A RESEARCH COURSE FOR MECHANICAL ENGINEERS

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ABSTRACT

At the University of Twente, students in their third year of the bachelor programme in Mechanical Engineering participate in the course 'Introduction to Technological Research'. The course has a study load of 6.5 ects (182 hours) spread over two quartiles. The course is part of the bachelor completion. During the course students have to engage in literature review on a given topic and write and present a research proposal. During the past years, this course has experienced some major problems with student motivation. Evaluation scores were low and students were leaving the bachelor with a negative image of research practice.
A redesign of the course was made based on the self-determination theory (Deci & Ryan, 2000), a theory on intrinsic motivation. The self-determination theory states that intrinsic motivation of human beings can be stimulated by fulfilling three basic needs; competence, relatedness and autonomy. Based on these three pillars, a new design for the course was made where students were stimulated to take responsibility for their research project by making their own choices, cooperate with peers and completing the full research cycle in close cooperation with one of the research groups at the mechanical engineering department.
The first year the redesigned course ran, an extensive course evaluation was used to measure students' appreciation of the course. For this evaluation, a self-designed questionnaire with open and closed questions about appreciation of course elements was used. Results of the evaluation were positive. The majority of students indicated that they liked the course and their research assignment. Students especially appreciated the activities with peers. The overall evaluation score went up from a four to a seven. Based on the evaluation results, minor improvements were made to the course design.
The second year, a validated questionnaire was used to measure student motivation. Results show that intrinsic motivation is moderately high at the beginning of the course but is declining as the course proceeds. Possible causes for this decline are discussed. Also, recommendations are made to other lecturers who would like to stimulate and measure intrinsic motivation in their course or project.

KEYWORDS

Research Skills, Self-directed Learning, Active Learning, Motivation, Peer Review, Course evaluation, Standards 1, 2, 7, 8, and 12.

INTRODUCTION

The University of Twente is a research intensive university, situated in the east of the Netherlands. The University is known as a technical university and also a member of the 4TU federation, but offers both engineering and science programmes as well as programmes in social and management sciences. A total of ± 3.000 staff members and ± 9.500 students work and study at the university, spread over 6 departments. One of these departments is the department of Engineering Technology accommodating the programmes Mechanical Engineering, Civil Engineering and Industrial Design Engineering.

The mechanical engineering (ME) programme is the oldest of the three and exists of a three-year bachelor programme followed by a two-year master specialisation. Annually, approximately 120 students enter the first year of the bachelor. Since 2000, the educational concept of the programme is thematic project education. The bachelor phase is divided into different projects and related courses centred on a content theme (e.g. 'Energy & materials' or 'Designing a consumer product'). This educational concept was taken over in 2001 by Industrial Design Engineering from the start of the programme. During the recent bachelor innovation (2014-2016) the concept was implemented university-wide.

Until the bachelor innovation, ME did not have an individual bachelor assignment, but was finalised in the last semester with a mechatronics project and the course 'Introduction to Technological Research' (ITR). ITR is a 6.5 ects (182 hours) course that is spread over the last two quartiles of the bachelor programme. The course is divided into two parts. The first part is a series of lectures on several subjects that have not been taught in the bachelor programme up until this moment: tribology, rubber technology and elastomers. This part is followed by a knowledge test that determines if a student is allowed to proceed with the second part of the course. This second part is aimed at doing research. Students are presented with a global research problem, related to one of the content areas from the first part, for example road contact of rubber tyres. In groups of two students, a literature research is conducted to identify so called 'white spots' and formulate a more specific research question. Based on this research question, students write a research proposal that is presented during a closing seminar.

The problem with this course is, that for several years it scored poorly in student evaluations. The overall appreciation score was below 5 on a 10-point scale and students indicated that the two parts of the course did not match with each other. Also, students criticized the assessment method and indicated that they found the course to be demotivating. An additional problem was, that a negative image of research was growing amongst students; an image of research being dull and only theoretical and very remote from daily life.

The author was asked to make a redesign for the course in such a way that students will experience it as a relevant and motivating part of the bachelor programme and gain a more positive image of scientific research. The only condition was to maintain the same study load (6.5 ects) and duration (1 semester) of the course. Besides this, the course had to be suitable for a group of approximately one hundred regular students and twenty premaster students. Other limitations were not posed on the redesign.

THEORETICAL FRAMEWORK

As a starting point for the course redesign, several theories on motivation and learning were looked at. Because the course is dealing with third year students who have reached a certain level of maturity compared to for example first year students, also design principles for adult learning were examined. Self-directed learning (Deci & Ryan, 1985) is a theory that is mentioned in relation to adult learning as well as student motivation. When a student is learning in a self-directed manner, he or she is learning from his or her own desire to acquire more knowledge or skills regarding a certain subject.

Deci & Ryan (2002) distinguish four types of motivation that can be present in a learner during a certain learning activity (often in combination with each other, where one or two types are dominant). These four types are:

1) A-motivation (AM): it is not at all clear to the learner why he or she is engaged in a certain learning activity
2) External regulation (ER): the learner is engaged in a learning activity because this is asked or because not doing so will have negative consequences
3) Identified regulation (IR): the learner is engaged in a learning activity because he or she considers this activity to be useful or relevant
4) Intrinsic motivation (IM): the learner is engaged in a certain learning activity because he or she considers this learning activity as valuable, interesting or fun to do

Both identified regulation and intrinsic motivation have an internal drive, meaning that motivation to learn comes from the learner him- or herself (self-directedness). Engagement and commitment to an activity are highest with intrinsic motivation.

Ideally, to have an optimal learning process, every student is intrinsically motivated during all learning activities. However, this ideal is far from feasible. During every educational activity, a mix of the motivation types mentioned above are present in a student. The dominant motivation differs per student and per activity. What is possible however, is to stimulate self-directed learning behaviour by fulfilling certain basic psychological needs of a learner (Ryan & Deci, 2000):

a. Autonomy: being able to make your own choices regarding learning method, learning activities, materials and / or learning goals.
b. Relatedness: being part of a community and doing something that has a relation to practice or that has value to others (also called relevance or purpose).
c. Competence: feeling that the goals that were set are feasible, yet still challenging and seeing one's progress.

REDESIGN AND IMPLEMENTATION OF THE COURSE

The course redesign was made in cooperation with the programme director of Mechanical Engineering (also co-teaching the course). The basic principles for the redesign were based on the three basic psychological needs (Deci & Ryan, 2000) discussed in the previous section:

- The research experience that the student has in this course should match the research practice within mechanical engineering as much as possible (Relatedness).

- There is a focus on self-responsible learning. The student is hereby able to make his or her own choices regarding content, planning and approach (Autonomy).
- Various possibilities are available for students at various moments to receive feedback on their work (Competence).
- Students learn from and with each other during the course (Relatedness, Competence).

It was decided to let students experience the entire research cycle, from problem statement to presenting the results to an audience. To make room for this, the subject matter related to rubber technology, tribology and elastomers was removed from the course.
The course was divided into two phases. During the first phase, students performed a literature review based on a global problem statement that they received from the research group. Goal of this literature review was to determine what has yet been researched in this specific area and where the so called 'white spots' are. Based on this literature research, students formulated a more specific research question. At the end of this phase a literature review and research proposal were handed in. During the second phase, students performed the research according to the plan that was made in phase one. The results of the research were represented in a scientific paper. To conclude the course, this paper was represented at a conference (including lunch and proceedings) where students discussed their findings with each other and answered questions from the lecturers and the supervisors.

All research groups were asked to deliver several research problems with a study load of approximately 4 ects (112 hours) and a supervisor that would be available during the course to supervise the students and provide them with feedback. During the course students worked in groups of two. Besides this, two groups were assigned to each research assignment with the purpose of having a peer partner for each group that was sufficiently familiar with the content of the assignment. Approximately 120 students participated, meaning that more than 30 assignments were needed, divided over the research groups at mechanical engineering (in order to have some flexibility and sufficient choice for students even more assignments were needed, of which some ultimately were not chosen).

During an assignment market, students had the opportunity to gain information with the supervisors about the assignments and make their preferences known. The students were asked to hand in three preferences. A student-assistant was then burdened with the complicated task to divide 120 students (in groups of two) in such a way that as many students as possible were assigned to the research assignment of their first or second choice. In most cases this succeeded. Where it wasn't possible to give students an assignment of their preference, a different assignment was chosen in consultation with the students, for example an assignment with the research group of their first choice.

Parallel to the research process, a series of lectures and tutorials was organised. During these lectures students learned about different aspects of doing scientific research: searching and reviewing scientific information, academic writing and research ethics. Besides general theory and guidelines, a lot of examples from the research practice at mechanical engineering were presented. Educational methods during these lectures were varied and active. Lectures were given by the author and the programme director as well as several guest lecturers with expertise in one of the topics.

In both phases of the course, a 'peer review session' was planned during which groups that were working on the same research assignments take a critical look at each other's work and give (content related feedback). The goal of this peer review is threefold:

a) Students learn to look critically at the research of another group and doing so, will also look critically at their own work.
b) It matches the research practice where peer review is common practice (e.g. when handing in a paper for a journal).
c) A limitation of the time that supervisors have to spend on giving feedback to concept versions.

Besides this, both phases also contained a feedback session where the supervisor from the research group met with all students that were doing an assignment from this group.
A series of walk-in lectures were planned throughout the course. These were not filled-in beforehand but were used as a possibility for students to ask questions, information on specific topics or feedback on specific parts of their work.

During the course, students are free to choose their own way of working. The only 'hard' deadlines are the deadline at the end of the first part (for handing in the proposal) and the deadline at the end of the second part (for delivering the paper). For the peer review and feedback sessions, it was not specified what had to be handed in. This could be a complete draft paper, but also just an introduction section. Emphasized was, that these feedback moments were planned to help them and that it was up to them to determine to what extent they wanted to use these. What was also emphasized was, that in principle everything was possible (e.g. altering the assignment, purchasing some materials for an experiment, extension of a deadline) as long as the students were proactive and took initiative to arrange things themselves.

Table 1 below represents the different parts of the redesign, divided by the basic need they address.

Table 1. Redesign components categorized by basic need

Autonomy	Relatedness	Competence
• Assignment choice • Own planning and way of working • Walk-in lectures • Room for own ideas and initiative	• Real assignment for ME research group • Examples from ME research practice • Walk through full research cycle including presentation of results	• Peer review • Regular feedback from supervisors • Feedback from lecturers • Conference presentation

METHOD

The first year redesigned the course ran, it was evaluated by means of an extensive questionnaire including open as well as closed questions. The questionnaire contained for example questions about the different aspects of the course, the supervision, working with peers and the assessment method. The questionnaire was placed on the learning platform (Blackboard) of the course and was administered twice; once half-way the course (after the proposal was handed in) and once at the end of the course. Finally, an evaluation meeting with all supervisors was held to capture their experiences and suggestions. Besides this, lecturers were asked for their classroom observations. Based on the evaluation results, small improvements were made for the second year.

The second year the redesigned course was conducted, a different evaluation approach was used. Instead of measuring student perception and course appreciation by using an extensive course evaluation questionnaire, student motivation was measured by using a validated Situational Motivation Scale questionnaire (SIMS) existing of 16 multiple choice questions (Guay, Vallerand, & Blanchard, 2000). This questionnaire measures the combination of the different types of motivation present in a learner during a learning activity, as described in the theoretical framework. Based on these outcomes, the degree to which a student is participating in an educational activity because he or she wants to be (self-determination) can be established. This was done three times during a lecture at the start, the middle and the end of the course. The questionnaire was combined with two open ended questions asking students what they liked and did not like about the course. Also, students were asked to grade the course on a scale from one to ten.

RESULTS AND IMPROVEMENTS

In this section, first the results of the extensive course evaluation questionnaire that was administered during the first year of the redesigned course are presented, followed by the improvements made to the course and results of the SIMS questionnaire that was administered during the second year.

Course evaluation questionnaire (year 1)

The course evaluation questionnaire was filled in by students at the end of the third quartile (n=46) and at the end of the fourth quartile (n=33). Results were positive. After the first part of the course, 50 percent of the students indicated that they liked the course, 43.5 percent were neutral. After the second part, 60.6 percent liked the course and 30.3 percent were neutral. Regarding the research assignments, after the first part 73.3 percent of the students indicated that they found their assignment fun to do, 13 percent were neutral. After the second part 72.7 percent found their assignment fun to do, 9.1 percent were neutral.

Table 2. Student appreciation of the course and their assignment

	Liked the course (%)		Assignment fun to do (%)	
	Positive	Neutral	Positive	Neutral
Quartile 3	50.0	43.5	73.3	13.0
Quartile 4	60.6	30.3	72.7	9.1

Most students (80.4 percent in quartile 3 and 75.8 percent in quartile 4) valued the things that were learned during the course as ‘relevant for a mechanical engineer’.
Students indicated to be satisfied with the supervision of the lecturers

During quartile three, most students were satisfied with the supervision received from the lecturers (69.5 percent) and their supervisors from the research groups (60.9 percent). During the fourth quartile this dropped somewhat with 57.6 percent being positive about the lecturers’ supervision and 51.5 percent about the supervision received from their research group supervisor.

Table 3. Student appreciation of supervision

	Supervision from lecturers (%)	Supervision from research group (%)

	Positive	Neutral	Positive	Neutral
Quartile 3	69.5	21.7	57.5	23.9
Quartile 4	60.9	36.4	51.5	21.2

Almost all students were positive about working in pairs (91.3 percent in quartile 3 and 93.9 percent in quartile 4) and also about working with two pairs on the same assignment (91.3 percent in quartile 3 and 93.9 percent in quartile 4).

Table 4. Student appreciation of group work

	Working in pairs (%)		Working with two groups on the same assignment (%)	
	Positive	Neutral	Positive	Neutral
Quartile 3	91.3	4.3	71.7	19.6
Quartile 4	93.9	3.0	78.8	15.2

The peer review sessions were appreciated positively by most of the students. After the first part of the course, 69.6 percent of the students indicated that they found the peer review useful. 43.5% of the students found the activity fun to do. After the second part, again 69.6 percent of the students found it useful. Almost half of the students (48.5 percent) found it fun to do.

Table 5. Student appreciation of peer review session

	Peer review useful (%)		Peer review fun to do (%)	
	Positive	Neutral	Positive	Neutral
Quartile 3	69.6	23.9	43.5	34.8
Quartile 4	69.6	6.1	48.5	36.4

The peer review sessions were valued positively by most of the students. After the first part of the course, 69.6 percent of the students indicated that they found the peer review useful. 43.5 percent of the students found the activity fun to do. After the second part, again 69.6 percent of the students found it useful. Almost half of the students (48.5 percent) found it fun to do.

The final conference was only evaluated after quartile 4. About half of the students (48.4 percent) found the conference fun to do, 27.3 percent were neutral.
The main criticism about the course was about the book. After quartile three, 15 percent of the students were positive about the book (45.7 percent were neutral). After the fourth quartile, 0 percent of the students were positive and only 9.1 percent were neutral. All others (90.1 percent) were negative.

The overall course as graded (on a scale from 0 to 10) with a 6.9 for the first part and a 7.0 for the second part.

Answers to the open ended question ‘What did you like about this course?’ varied a lot. The aspects most mentioned were: the final conference (n=7), the possibility to choose from different assignments (n=8) and getting acquainted with doing research (n=11). Suggestions for improvement that were mentioned most were focused on the consistency of the assessment between supervisors (n=6) and on the book (n=8).

Minor improvements

Based on the evaluation results of the first year of the redesigned course, some small improvements were made to the course. The book was replaced for a different one and a set of hand-outs on practical skills needed for the course (e.g. paper writing and academic English). To enhance consistency between assessments of different supervisors, the assessment formats for the research plan and paper were improved and discussed in a meeting with the supervisors. Finally, some measures were taken to strengthen the link with practice. Guest lecturers were added to present interesting examples from ME research practice. Also, more emphasis was placed on the societal impact of research. A guest lecturer from the philosophy department was invited to give an inspirational lecture about the topic and students were asked to integrate societal impact into their research proposal and paper.

SIMS questionnaire (year 2)

The SIMS questionnaire was filled in by students at the start of the course (n=79), halfway through the course (n=56 and at the end of the course (n=55). Below, the results from the three measurements are represented in a table and a graph.

Table 6. Results of the SIMS questionnaire

	Start	**Halfway**	**End**
Number respondents (N)	79	56	55
Intrinsic Motivation (IM) (μ)	4.2	3.9	3.7
Identified Regulation (IR) (μ)	4.8	4.5	4.4
External Regulation (ER) (μ)	4.9	5.0	5.0
A-motivation (AM) (μ)	2.2	2.5	3.0

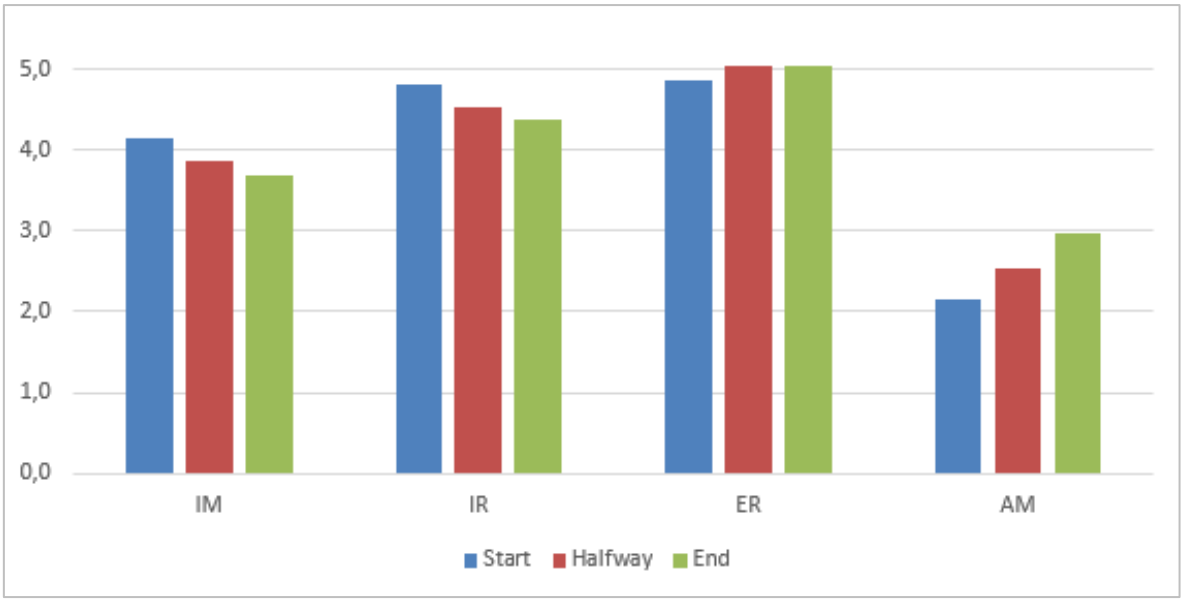

Figure 1. Motivation at the start, halfway and at the end of the course

When we look at the results of the SIMS questionnaire, we can see that at the beginning of the course, intrinsic motivation and identified regulation are fairly high, but that external regulation is also high. From the start of the course motivation is mixed, with a focus on the self-directed types of motivation. During the course however, intrinsic motivation and identified regulation decrease and a-motivation increases. This is in line with the grades the students give to the course. At the beginning of the course the average grade is 6.9, decreasing to a 6.6 halfway the course and a 6.4 at the end of the course. Even though the decrease is small, motivation and course appreciation of students are going down as the course proceeds.

Answers to the open ended questions halfway the course are varied. Aspects students liked about the course were conducting the research experiment and experiencing research in practice (n=22), the freedom of choice and independency (n=13), gaining insight in the world of scientific research (n=10) and the assignment itself (n=8). To the question 'What did you not like about the course?' comments were made mostly on uncertainties regarding expectancies or how to approach the assignment (n=9), the writing process (n=8), the assignment and its results (n=6) and problems with supervision (n=6). At the end of the course, the same aspects were emphasized. What was added were comments about the amount of guest lectures and their direct relevance for the course work (n=16).

DISCUSSION

Results showed that besides internal types of motivation, external motivation is also high. A possible explanation for this is, that doing research is just not something that appeals to the average bachelor students at mechanical engineering. They tend to prefer the more technical courses and projects and picture themselves working as a designer or technical consultant rather than as a scientific researcher. Also, this course is (together with a mechatronics project) the last course students have to pass in order to obtain their bachelor degree. This might also add to the feeling that this is something they have to do instead some something they that is by itself fun and interesting. .

Besides this, we can see that in the second year the redesigned course ran, intrinsic motivation and course appreciation were decreasing, where it stayed stable during the first year. An explanation could be that a different group of students can react differently to the same course activities. During the first year, about 20 percent of the students were premasters who generally are a bit older and have a higher intrinsic motivation than the regular bachelor students. During the second year the premasters were participating in a separate course for premaster students and not part of the regular bachelor course anymore.
Also, during the second year, we decided to let students work more independently and have less guidance during the walk-in lectures. At the same time, there were some problems with absent supervisors and we decided to have less coordination meetings with the supervisors to take away some of the workload for everyone. Perhaps this combination of less coordination and problems with supervisions made students feel like they were 'thorn into the deep end' too much as some commented in the open questions.
Adding the quest lectures was not very successful. Especially in the second half of the course, students felt that there were too many and that they did not directly contribute to the course work. This might also explain the decrease in course appreciation.
Some students were disappointed because the assignment, that seemed very interesting at first, turned out to be not what they expected or became frustrating when experiments failed, causing their motivation to go down.

Finally, the SIMS questionnaire is a measurement of the state of someone's motivation at a certain moment (snapshot in time). It is also possible that at the moment of the measurement students were less happy because they were struggling on writing the paper or getting their measurements right before the deadline. This could strongly affect someone's motivation at a certain moment. A standard course evaluation looks back on a longer period where the frustration that was experienced at certain moments has less influence on how one appreciates the whole course.

CONCLUSIONS AND RECOMMENDATIONS

Using the self-determination theory as a basis for redesign and focusing on the three psychological basic needs 'Autonomy, Competence and Relatedness' did help to design a course that was more motivating for students. What worked well was the freedom of choice (Autonomy), the peer learning and peer feedback (Relatedness / Competence) and the link with the real research practice of mechanical engineering (Relatedness).

This is however no guarantee for having intrinsically motivated students. I remains a quest for what works and it is often hard to predict how students will react to changes made. Giving more autonomy to students works well, but giving too much autonomy can give students the feeling that they are left alone. The same goes for inspiring examples from practice. These can be very motivating, but without a direct link to the course work in combination with a high workload, they can be perceived as a waste of time and demotivate students.
Using the SDT as a basis for redesign can offer guidance for thinking about more motivating methods and approaches in a course. For this course we will continue to follow this path to self-determination, keep the successful things and replace the unsuccessful for new ideas in consultation with students.

Some recommendations for lecturers who also would like to make their course more self-directed:

- Look where you see possibilities to offer students choices in content, working methods or materials. Make sure to combine this with clear structure and guidance so students don't get lost in their options and responsibilities.
- Peer review is a good way to let students give feedback on each other's work. Students learn from each other, but will also start to look critically at their own work while comparing with others. Using a format based on the assessment criterial will help students to focus their feedback on the relevant aspects.
- Think about ways to make a link with professional practice. This could be an assignment for a real client, but it could also be done with an excursion, experiences from practice (e.g. from alumni) or examples of current applications.
- Use a combination of motivation measurement with a standard course evaluation to help you interpret the results. The SIMS questionnaire is one example, but there are also other options, for example on the SDT website (University of Rochester, c2017).
- If you would like to get inspired and know more about motivation theory, there are several books available that give a compact and accessible summary of scientific findings on motivation and applications in practice, for example Deci & Flaste (1996) and Pink (2011).

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