Paper 102. Engineering students become sustainable practitioners by combining profound learning and sustainable education

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Abstract

In our vision engineering students become sustainable practitioners by focusing on their learning process instead of focusing on their engineering results. By focussing on the learning process we create a learning environment in which there will be innovation because it's permitted (or even requested) to make mistakes and learn from these mistakes. The learning of the students is driven by assessments for learning [Dochy] and emphasis on competence, relatedness and autonomy, the key factors of the Self-Determination Theory (SDT) [Deci & Ryan]. We believe that profound learning and sustainable education are inseparable.

In the minor program Innovation, Engineering and Design in our Industrial Design Engineering course we combine assessments for learning, SDT with sustainable design methods and LCA. In this minor program student are working on real live projects. All projects are demand driven, the demand owners are private companies. Beside the companies, the research department of our university provides open research questions. We translate these research questions to objectives for the companies and professional products for our students. In this way, we apply the triple helix of industry, research and education. Even more, we try to make it a sustainable triple helix by inviting the entrepreneurs to join our learning processes and, by doing so, constructing a basis for innovation. We try not to solve problems for the companies, but to learn and innovate with the companies.

In the paper we will explain the process by sharing a recent project:

The project for the company Visser Group, 's-Gravendeel, the Netherlands, is aimed at developing a new production technique of injection moulding cores. The main question that was brought in by the company and the Rotterdam University of Applied Sciences, research department of Sustainable Development, was to develop injection moulds using additive manufacturing techniques.

The students and teachers started without deep knowledge of additive manufacturing processes and they never used a injection moulding machine. The project focused on learning new skills and knowledge and not on the end result. The learning is driven by the collaborative action research method [Lewin] and an uncertain but sustainable goal; a perfect example of engineering by doing.

1 Introduction

In the school for Industrial Design Engineering at the Rotterdam University of Applied Sciences it's common to work with companies projects in each grade of the bachelor program. During the years we gained a lot of experience with projects that facilitated the learning of the students well and provided a satisfying result for the industry. Sometimes the research department of the university was also pleased with new knowledge developed in these projects. Not all projects led to good results for all stakeholders. Starting from this practice based knowledge, we developed a learning context for profound learning in which all stakeholders are part of a sustainable learning environment. This learning context is based on theory of profound learning, motivation and collaborative research.

In the minor program Innovation, Engineering and Design in our bachelor Industrial Design Engineering course we combine assessments for learning, SDT with sustainable design methods and LCA. In this minor program, we have 16 different projects and 45 engineering students executing these projects in teams. All projects start demand driven, the demand owners are private companies. Beside the companies, the research department of our university asks open questions in its research programs. We translate these research questions to objectives for the companies and professional products for our students. In this way we apply the triple helix of industry, research and education. Even more, we try to make it a sustainable triple helix by inviting the entrepreneurs to join our learning process and by doing so constructing a basis for innovation. We try not to solve problems for the company, but to learn and innovate with the company.

2 Theory of sustainable learning

A sustainable learner is a someone who uses deep learning strategies and is able to manage his learning (Sluijsmans, 2008). In-depth learning (deep learning) is about giving meaning to the task and integration of knowledge in the total knowledge. This form of learning is driven by intrinsic motivation (Segers, 2008). Also Schunck (2008) indicates that a student learns better from intrinsic motivation: "(…) working on a task for intrinsic reasons is not only more enjoyable, there also is evidence that across all grade levels, intrinsic motivation relates positively to learning, achievement, and perceptions of competence, and negatively to anxiety" (Schunk, 2008, p. 238).

2.1 Intrinsic motivation

According to the self-determination theory (Deci & Ryan, 2000), intrinsic motivation appears as students perform an activity because they enjoy the activity itself. This theory distinguishes different stages of motivation:

- Autonomy: The higher the perceived autonomy and the less pressure is being experienced, the higher the intrinsic motivation.
- Competence: Students must find tasks that are challenging but not too difficult.
- Social connectedness: Lack of social connectedness leads to a decrease in intrinsic motivation.

Learning and assessing are related. Developments in (higher) education towards competence-based learning and demand driven learning forces us to judge an assessment no longer as an didactical problem, but to see it as a design problem. Sluijsmans (2008) gives three areas on which to focus applying sustainable assessing:

1. Designing learning environments in which sustainable assessment and demand-driven learning are the key elements.

2. Communicating about assessing.
3. Self-steering at assessment by the student.

2.2 Assessment for learning

In an assessment for learning (AFL) is in addition to the product of the learning process the learning process itself assessed. This AFL gives a student understanding of his learning process. This understanding provides information to the teacher on the educational process and on possible interventions.

The relationship between the success rate of the student and the AFL must be found in the positive effects on the learning of the student. The purpose of portfolio assessments, according to Dochy & Nickmans (2005), is that in this type of assessment also the process of learning is evaluated in addition to the product of the learning process. It gives students insight into their learning and evidence of possible interventions. The key for learning is the feedback that the student is given in his assessment.

2.3 Feedback on learning

Hattie (2009) relates many effects of education to the teachers. The teacher is the main instrument to achieve effective learning. The main tool the teacher can use, according to the impact study of Hattie, is feedback.

The single most important element of assessment supporting learning, is the frequency and type of feedback provided during the assessment (Gibbs & Simpson, 2004). Feedback that supports learning:

- is frequent and sufficiently timely to the task so that it still matters to the student,
- is focused on student performance and learning, rather than student characteristics,
- is specific and detailed, addresses small chunks of material, and provides guidance for future efforts matches the purpose of the assignment and encourages the student to improve,
- is supported by mechanisms that require the student to attend to and act upon the feedback.

Teaching students to monitor their own performance should be the ultimate goal of feedback. Continuous support for improving these skills will help students transfer learning to new situations and become effective lifelong learners (Gibbs & Simpson, 2004).

3 Learning context

"School leaders and teachers need to create a learning environment where error is welcomed as a learning opportunity, where discarding incorrect knowledge and understanding is welcomed, and where participants can feel safe to learn, re-learn, and explore knowledge and understanding."

(Hattie 2009)

3.1 Project based learning

A standard educational project the Rotterdam University of Applied Sciences offers project based learning. The objectives in the projects are real problems from real companies. As shown in figure 1 the company askes a problem solving question to the research department. The problem solving question is translated to a knowledge question to teachers who then translate this knowledge question to a learning question for the student. In this situation there often is no satisfying result for the research department and the company. The student learning will be achieved, but it is hard for the teacher to

motivate the student. This motivation is often extrinsic and does not lead to deep-learning (Deci & Ryan, 2000).

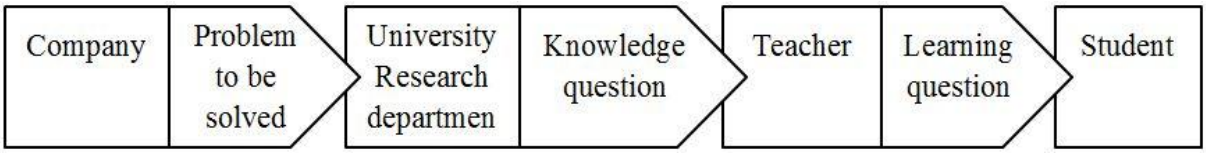

Figure 1: learning context project based learning.

3.2 Triple helix learning environment

The minor program Innovation, Engineering and Design in our Industrial Design Engineering course combines ASL, SDT with sustainable design methods and LCA. In this minor program, we have 16 different projects and 45 engineering students working in teams on these projects. All projects start demand driven, the demand owners are private companies. The research department of the university ask open questions in its research programs. The teachers translate these research questions to objectives for the companies and professionals products for the students. The university offers a safe environment where mistakes are welcomed. This environment is also created for the companies and researchers. The university organizes conditions for lifelong learning. In this way the triple helix (figure 2) of industry, research and education is applied. Even more, it is a sustainable triple helix by inviting the entrepreneurs to join the learning process and by doing so constructing a basis for innovation instead of problem solving.

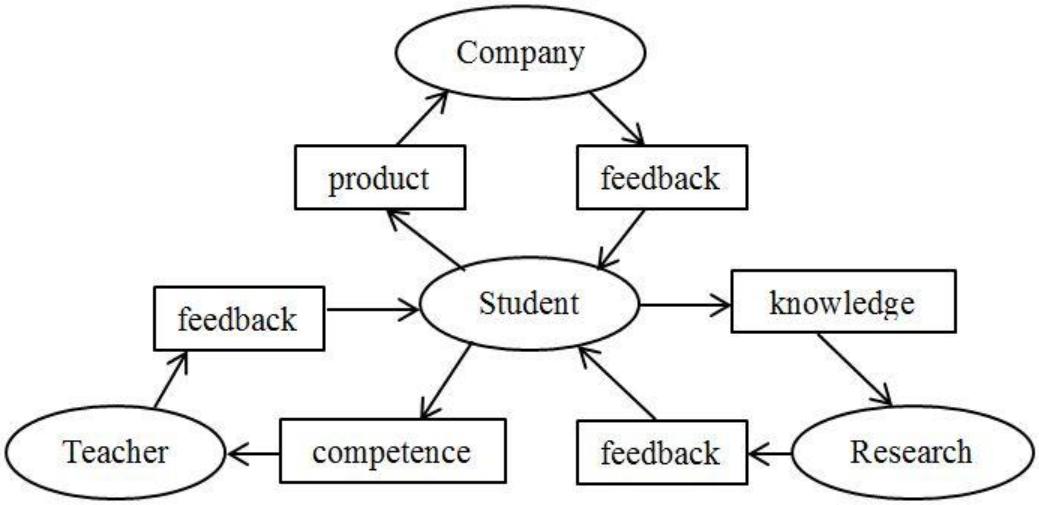

Figure 2: triple helix learning environment

3.3 Collaborative learning

Based on SDT, the triple helix learning environment gives autonomy to the students, leads the project and reacts on the different stakeholders. Because each stakeholder desires a different result, the student has autonomy to all stakeholders in a different way. All stakeholders know that the learning of the student is the core of the project and that the students have to make mistakes to achieve this learning. For an innovative sustainable product companies need someone who is willing to experiment and find new ways (design methods) and knowledge to solve their problems. Most companies do not facilitate

their own staff to experiment and companies cannot afford to make mistakes. As a University of Applies Sciences, we succeeded to position the student in the centre of the triple helix through autonomy for the student and the opportunity for the student to make mistakes. Student-centered learning implies a "need for students to assume a high level of responsibility in the learning situation and be actively choosing their goals and managing their learning. They can no longer rely on the lecturer to tell them what, how, where and when to think. They must start to do this" (Sparrow, Sparrow & Swan, 2000).

Collaborative learning environments with emphasis on process, rather than product, engender this type of interactive learning (Salmon, 2000). Collaborative learning, or co-learning, is the process of co-creation of valued knowledge. In the triple helix learning environment the stakeholders, together with the students, participate in a collaborative learning process.

4 Role of the teacher

The teacher has two roles in the triple helix for learning. The first is the role of coordinator of the learning context. Hereby the teacher informs the stakeholders (company, research and student) about the correct understanding of collaborative working in the triple helix learning environment. By doing this, the teacher has to give over the coordination to the student in an early stage, at least before the real objectives of the project have been determined. The detemination of the project objectives must be lead by the students to gain autonomy. Through the project the teacher must work on a safe learning environment and relationship between the stakeholders and so become a co-learner himself.

The second role of the teacher is the role of coach to the student. The teachers coaches the student to learn en develop his competences. The teacher focusses on the learning process of the student. The teacher checks if the described task for the student, which is described together with the company and research department, is not too complex or too simple and will fit the students ability for learning. At the end of the project the teacher will coach the student to manage an evaluation with all stakeholders involved. The assessment of the project is an assessment for learning of the competences learned. The end result cannot fail, all parties are focused on this.

In both roles the teacher has to focus on feedback. This feedback is focused on learning, knowledge and product. The teacher gives feedback when needed by the student and supports all stakeholders to give feedback to the student as often as possible .

5 Example: the Minor project

An example for this student centred way of sustainable learning is the project from the Minor program Innovation, Engineering and Design. The project for the company Visser Group, 's-Gravendeel, the Netherlands, is aimed at developing a new production technique of injection moulding cores. The main question that was brought in by the company and the Rotterdam University of Applied Sciences, research department of Sustainable Development, was to develop injection moulds using additive manufacturing techniques.

5.1 The stakeholders in this project:

- Company, Visser Group: a specialist in injection moulding.
- Research, S.M. Persaud: Research teacher research topic: additive manufacturing.
- Teacher, S. Blom & M. Smit: Industrial Design Engineering.

- 3 students Industrial Design Engineering, 4th year.

The students, company and teachers started without deep knowledge of additive manufacturing processes. Teacher, researcher and students never used an injection moulding machine before. The learning is driven by the collaborative action research method and an uncertain but sustainable goal.

The company was looking for a way to make test moulds in a time efficient way. The Research teacher was investigating the possible applications on a Z-Corp 3D printer. The student project was aimed at innovation and sustainable solutions. The teacher therefore coached the students on sustainable design methods and innovation.

Before the start of the project some research is already done by teacher Persaud on the possibilities for creating a 3d printed mold. He also contacted company Visser Group to investigate the possibilities to make a bio root cage with a 3d printed mold. Teacher Blom takes the project as a minor project and organizes a first meeting between the student group, researcher Persaud and company Visser Group.

The student group is given the task from Minor to make a 3d print mold a design. Hereby the group can interact freely with all stakeholders involved.

5.2 Analysis Phase

In the analysis phase the student group investigated the current situation from the company and the features of the 3D printer. Hereby they independently communicated with all parties involved. The open communication quickly showed the possibilities and limitations of the stakeholders about the following topics: project planning, research, available earlier research, literature, experts, possibilities of prototyping at the various locations and the experiment itself on injection molding machines, 3D printing and mold making.

5.3 Design Phase

The problem ofthe company Visser Group is to find a solution to produce a bio root cage. The experts at Visser Group have knowledge of injection molding and of the product, the experts at the Rotterdam University of Applied Sciences have knowledge of design and research, the other companies involved have knowledge of rapid prototyping techniques or rapid prototyping materials. The students are familiair with design and the theory of injection moulding, but not with the topics of rapid prototyping techniques and rapid prototyping materials. To find possible solutions for the problem the students are training their skills in all areas: there is an intense period of 3D printing, injection molding and mold making. This period can be characterized as critical trial and error. Indications of the experts are translated into experiments. The findings, successes and failures of their experiments they then shared with all stakeholders. The parties provided appropriate cooperation and gave feedback on the new knowledge. This lead to three possible solutions. The company gets the material and products for free in return of publication of the results.

5.4 Test phase

In the workshop of the Rotterdam University of Applied Sciences experiments for the three solutions were guided by the researcher Persaud. Company Visser Group assisted the students and researcher Persaud when operating the injection moulding machines. Three different moulds have been placed on the machines, each provided by a third party, on the basis of specifications developed by the student group. All the tests involved were not previously performed. The students have discovered the correct settings for the machines with the testing. The final results are different for the three possible solutions,

but all parties involved are very satisfied with the knowledge gained. Without the students as a connecting factor, the research and the knowledge had not been realized.

6 Findings

Sustainable education and profound learning is all about the learning process. For this a learning context in wich mistakes are welcomed, is to be developed. The assessment is based on learning and not on the result. The end result can fail but the learning will not. All involved parties must be aimed at this student centred approach which will lead to a safe and open relationship between student, company, researcher and teacher. In this context sustainable innovation is possible through learning by doing.

For a researcher this is obvious, but for a company this is not. Companies are usually focused on the end result of a project. The Universities main focus is the development of the student. The student must understand that the end result is less important then his learning process. To achieve this, the company must be convinced too that it is important to steer on the learning of the student and their own, instead of steering on the end result. This will require a research question with an open end where each party has to learn.

Key elements:

1. Co-learning in a triple helix with the student in the centre. Stakeholders (student, company, research and teacher) meet the following criteria:

- For each stakeholder the research question is new, the solution is unknown.
- Each stakeholder is a co-learnir and hereby each party is invited to amaze itselve and to share.
- Each stakeholder shall develop knowledge and skills and thus climbs into competence.
- In a small team there is a greater responsibility and better connection between the parties, in a large student group the projects are divided into small student groups (3 to 4 students) with their own triple helix learning environment, including a company and unique research question.

2. Open question: so there are various approaches that can be researched.

3. Milestones of the project (not too far apart) focussing on (formative) assessment for learning and giving enough feedback and feed forward on the stakeholders learning.

When all key elements are well organized and monitored during the project, the learning is profound for all stakeholders and thereby a perfect example of sustainable education and a basis for innovation instead of problem solving.

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