**NordDesign 2016**
**August 10 – 12, 2016**
**Trondheim, Norway**

# Student-developed laboratory exercises - An approach to cross-disciplinary peer education

**Fredrik Henriksson[1], Kerstin Johansen[1], Renee Wever[1], Patrick Berry[2]**

[1]*Machine Design, Linköping University*
*Fredrik.henriksson@liu.se, Kerstin.johansen@liu.se, Renee.wever@liu.se*
[2]*Fluid and Mechatronic Systems, Linköping University*
*Patrick.berry@liu.se*

**Abstract**

With new technologies and demands from industry, universities need to adapt in order to educate engineers suited for the job market of tomorrow. Focusing on the fields of product development and mechanical engineering, topics such as new lightweight materials and lightweight designs are currently a focus of many industries, and the demand from industry is that engineers graduating should have some knowledge in these fields. In this case, a project was set up for a student-developed laboratory exercise in lightweight material, focusing on the interconnection between material properties, geometry and manufacturing technology in order to fulfil a contextual requirement. The industry chosen was the aircraft industry, due to its heavy emphasis on light weight. The chosen component (a civil aircraft radome) meant that material properties not necessarily connected to high specific strength became important, something that adds educational value to the exercise. Since the introduction of the exercise, the plan is to introduce the laboratory exercise in more courses where the interdisciplinary connections between material properties, geometry and manufacturing technology needs to be explained for students as well as evaluate how this approach to exercise development can be improved and further utilized. This paper presents the learnings from setting up the laboratory exercise, as well as discusses the possibilities of thesis works as an enabler for peer education and puts these in a context for a future, adaptive engineering education that quickly can add or renew material in the curriculum without substantial investment of resources.

***Keywords: Design engineering education, peer education, materials for design engineering, experiential learning***

## 1 Introduction

Products in high technology industries such as automotive or aerospace have become increasingly more complex (Elverum & Welo, 2014), and with the industrialization of technologies such as mass production in fiber reinforced polymers and additive manufacturing, the design space for engineers become larger. Along with these new technologies and new products come new demands from industry, demands on the capabilities of graduated engineers. This emphasizes the need for universities to be adaptive in order to educate engineers well-suited for the job market of tomorrow. But how can this be achieved, without increasing the workload on academics working with teaching?

In mechanical engineering and engineering design; geometry, material and manufacturing processes are three interdependent parameters in the product realisation process that needs to be attended to. Most if not all other design parameters can be described as functions of these three fundamentals. According to Henriksson and Johansen (2016), the optimum product can be described as an optimum compromise between the three fundamental parameters. While being three interdependent topics, engineering materials, engineering design and manufacturing technology are often taught separately in engineering education. This gives that students might not realize the intimate connection between the three topics (or decisions within the design process).

Peer education, defined as "people from similar social groupings who are not professional teachers helping each other to learn and learning themselves by teaching" (Topping K. J., 1996) (though what constitutes a "peer" is not always clearly defined (Shiner, 1999)), has been deemed to be an effective and efficient approach to teaching. Interdisciplinary fields, like design engineering where diverse experience backgrounds of teachers and students can enrich the outcomes of design projects, are particularly suited to peer learning approaches. For example, Jansen (2015) describes the development of a minor in sports innovation, applying peer learning to a program that is open to students from design and engineering programs as well as Human Movement Science, the program running with students originating from eight different majors.

Due to the many mono-disciplines contributing to Design Engineering, the notion of "peers" is a bit wider than usual. In the strictest interpretation, peers would be students from the same program and cohort, and a bit wider interpretation might also include senior students from previous cohorts. However, in Design Engineering, junior students from contributing mono-disciplines, might also be seen as peers to more senior design engineering students due to their specialization in a certain field. The literature describes several examples of peer learning in a design engineering context. These range from classic peer learning, such as described in Wever & de Eyto (2013), where students from the same course reflect on each other's written texts. The course described in that paper did include students from different master's programs though, covering amongst others Integrated Product Design, Strategic Product Design, Industrial Ecology, and Management of Technology. An example of peer learning between senior students and more junior students is described in Wever & Christiaans (2010) where PhD students collaborate with senior BSc students on a small research project. An example of mono-disciplinary junior students working with senior interdisciplinary design students is Willemsen (2012) where a BA student in English first studied the academic writing skills of MSc design students, and later continued to coach them.

Such examples of mono-disciplinary students – irrespective of whether they are in more junior, equal, or more senior cohorts – collaborating with inter-disciplinary design students, is what we will call cross-disciplinary peer education. In light of the potential advantages in both efficiency and effectiveness of cross-disciplinary peer education, this paper describes a case study on a lab exercise developed by a mono-disciplinary student for their inter-disciplinary peers. The lab exercise is subsequently assessed both for its potential efficiency and effectiveness compared to more traditional teaching development.

At Delft University of Technology, the Industrial Design Engineering bachelor program contained a research project for many years, where students had to perform an independent research study under the guidance of a researcher (Wever & Christiaans, 2010). Many of the researchers participating within this course were PhD candidates, that had only graduated from the Industrial Design Engineering program recently and had the ability to connect well with the level of research understanding of third-year bachelor students.

# 2 Purpose and aim

The purpose of the project was to investigate new ways of approaching peer education in academia, and discuss how this can be implemented to ensure adaptability in the curriculum and the capabilities the students can acquire during their studies. This was done via the implementation of a student thesis project with the goal of developing a laboratory exercise for programme students in a similar but not equivalent field.

# 3 Peer education

If teaching is described by the didactic triangle of "who", "what" and "how" (Klette, 2007 via Helgevold, 2016), peer education is an approach to increase learning outcomes via altering "who" are teaching. Peer education have been researched since the sixties, and while it has shown that students affect each other's learning (Damon, 1984), no clear-cut framework has been adopted by practitioners of the field (Shiner, 1999). Even without this framework, peer education approaches have been shown to be successful in design engineering related fields (Elata & Garaway, 2002). Walker and Avis (1999) identified seven reasons why peer education fails:

- Lack of aims and objectives
- Programme design inconsistent with external factors
- Lack of investment
- Underestimation of the complexity of peer education
- Inadequate training and/or support for educators
- Boundary issue ambiguity
- Lack of multi-agency support

To mediate these failure modes, peer education needs to be planned ahead and implemented in a structured way, as opposed to bringing students together ad hoc (Topping K. J., 2005).

Assuming general assessments and class-room presence for both tutor and tutee, peer education can be categorised via two different qualities:

1. Are the tutors and tutees in the same year of study?
2. Is the tutor handling more than one tutee at the same time?

This gives four different categories of peer tutoring as seen in Table 1. These categories have been further expanded on by Topping (1996).

**Table 1. Categorization of different approaches to peer education (Topping K. J., 1996)**

| | ***Tutors and tutees in same year of study*** | ***Tutors and tutees in different year of study*** |
|---|---|---|
| ***Tutor assisting one student at the time*** | Same-year dyadic tutoring | Cross-year dyadic fixed-role tutoring |
| ***Tutor assisting more than*** | Same-year group tutoring | Cross-year group tutoring |

| | | |
|---|---|---|
| ***one student at the time*** | | |

Peer learning initiatives have shown to have positive effects on the psychological well-being of college-level students, regardless of race, gender or academic ability and thus also indirectly enhance academic performance for different students (Hanson, Trolian, Paulsen, & Pascarella, 2016). The peer education activity can be viewed from perspectives of both tutor and tutee, the authors have separated these perspectives into “peer learning” (taking the perspective of the tutee) and “peer teaching” (taking the perspective of the tutor).

According to Damon (1984), feedback from a peer can be both more direct and less threatening than if a senior had presented the same feedback. In topics where lay experience is highly valued, students can feel that peers are more appropriate teachers than expert professionals (Shiner, 1999).

Peer teaching have been shown to be positive for learning outcomes, in the simplest form by the old saying “to teach is to learn twice” (Topping K. J., 1996). The activity can help communication skills, something that has been shown to be of importance in engineering education (Waitz & Barrett, 1997). Already preparing for peer teaching has shown to generate positive results on conceptual understanding (Topping K. J., 1996).

# 4 The teaching environment at Linköping University

Teaching in engineering design-related topics at Linköping University is regularly done in case project settings, developed from the CDIO initiative in the early 2000s. This applies also to aeronautical engineering. More recently, an initiative to encourage learning about materials in an integrative manner have been taken with the introduction of the Material Realisation Laboratory environment.

## 4.1 University education in the Nordic countries

Higher education in the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) is typically characterized by a high level of student freedom and influence, as well as an emphasis on equality and accountability towards society (Fägerlind & Strömqvist (Eds.), 2004). While global university rankings are of some interest also for the Nordic universities, their impact on strategies and policies seems to be minor (Elken, Hovdhaugen, & Stensaker, 2016). Instead, internationalization of education has a significant impact on strategies and policies in the Nordic region (Fabricius, Mortensen, & Haberland, 2016).

## 4.2 Teaching in aeronautical engineering at Linköping University

Aeronautical education at Linköping University is basically traditional, except for one major part; during the last year, education is mixed with practical work in the Aircraft Project Design course. Other universities also have aircraft design projects but they rarely reach the state of eventually building and flying their designs. The traditional approach of paper plane projects, while useful, leave little or no room for practical applications or detail design: for obvious reasons, the design loop cannot be closed. Large or full scale projects are out of the question, due to budget constraints and the tight time limit to every project run as a university course.

A possible answer to this dilemma would be to design and build downsized demonstrators of full scale designs, i.e. doing a little bit of both worlds. In 1999 this approach was implemented in that year's project: a solar powered aircraft. The students wanted to do it for real, so the faculty made it happen and it turned out very successful. While there were some initial doubts to the model aircraft approach, these issues were mediated successfully through back up lectures on items lacking in the project course. The other concern was how to avoid the project being treated as just another playground for students without major learning benefits. With time, this turned out not to be an insurmountable issue: the Aircraft Project Design course turned out a number of successful projects, accompanied with very pleased students.

To upgrade model aircraft design to the level of "real aircraft design", model aircraft design has to be treated the same way as real aircraft design, with all activities such as sizing the aircraft from a specification, identifying weight design targets, creating the structural layout, analysing for minimum weight, verifying calculations by testing and others.

The process of work is much the same as in real aircraft design, but more controllable in comparison. There are several benefits that can be envisioned by the model aircraft approach:

- The approach motivates students by enabling them to implement their knowledge
- The approach closes the design loop. Students are involved in all aspects
- The approach integrates under- and postgraduate research around one common project
- The approach enables integration of skills across disciplinary areas within the university

### 4.3 The Material Realization Laboratory environment

In 2010 a laboratory for viewing and experience material was introduced as a pedagogical platform at Linköping University in Sweden, called Material Realization Laboratory (MRL). The platform was developed based on observations that students either did not know the difference between different wood based materials or that students easily rendered surfaces in different CAD software, without understanding the behavior or properties for the selected material. The platform of MRL is today a room that consists of about 500-600 pieces of material samples (see Figure 1) divided into different material categories. The room is organized as a material library with easily accessible material data for all samples and other sources for more information. Material is also searchable via traditional search methods through the Linköping University library website (LiU E-Press, 2016).

The aim with MRL is to encourage students to explore different aspects on material selection for a product or component by supporting them with material samples and material data in an inspiring environment. One implementation of this has been practical and theoretical laboratory exercises engaging students to explore materials from different perspectives, such as how material and production technology interact by discussing material choices in products and the production methods used. The MRL platform has been a success based on surveys to students, and the number of courses that uses the library are increasing gradually – at the moment there is about eight courses excluding project courses that have pedagogical moments in MRL.


**Figure 1. A view of MRL at Linköping university (Photo: Kerstin Johansen, 2013-09-19)**

# 5 The case

The project was prepared by a supervisor and examiner, by writing a project description including a short background, problem description, expected outcomes, examining activities, official time plan project gates, steering group and suitable initial references.

One of the demanded deliverables was a time-set laboratory exercise investigating the relationship between geometry, material and manufacturing process when looking at lightweight solutions in aeronautical design. The choice of component was not set in the project preparations, but instead used as one of the early milestones in the thesis project.

The student performing the thesis project was an Aerospace engineering student on bachelor level, from UP Madrid. From the beginning, an emphasis was put on including the manufacturing aspects as well as design in the project outcome.

# 6 The result

## 6.1 The laboratory exercise

The laboratory exercise investigates the development of a civil aircraft radome (the nose of the aircraft, containing radars and sometimes other instruments). The work starts with introducing the component, and the students are supposed to brainstorm around requirements (see Figure 2). This is followed by a discussion about material selection, from concept level material class selection down to fiber type selection. Later, design structure is covered and lastly the manufacturing process is discussed. The laboratory exercise alternates between beehive discussion groups and whole class questions.

## 6.2 Initial testing

Two initial tests on the laboratory exercise have been performed; one involving students and one involving senior academics. The second test, involving academics selected based on academic and professional expertise in fields related to the thesis topic (aircraft design, composite manufacturing, design engineering and integrated product and production development), served as the oral presentation of the thesis project as well as a test of the exercise. During the second test, minor issues were identified with phrasing of some questions, and some uncertainties were identified where the academics participating were not in agreement of which solution would be the best to the presented challenge.

# 7 Implementation

The laboratory exercise was implemented in an educational setting during spring 2016. In this implementation, the corresponding author conducted the session for a student group of 20 people during 120 minutes in the MRL environment. During the session, the student group was active and responsive to the conductor and initial reactions seemed positive. All groups discussed all topics given and were able to find possible suggestions, and while suggestions converged on some topics no topic hade a unanimous agreement between groups. At the time of publishing, the results from the course evaluation (which might include comments about the exercise) have not yet been published.

| Seq. | Task | Estimated time |
|---|---|---|
| 1 | Brief introduction about the laboratory work | 2 min |
| 2 | Presentation of the case of study. Including definition and scale model/pictures of the radome | 2 min |
| 3 | Division into groups of 4-5 participants | - |
| 4 | Discussion in groups about the specifications of the radome | 10 min |
| 5 | All in common: Determine all the requirements | 5 min |
| 6 | Introduction about lightweight materials | 2 min |
| 7 | Discussion with the participants between light alloys, composites and other possibilities. Including example materials from the MRL. (How do those materials allow us to reach those properties?) Choice of composites | 5 min |
| 8 | Brief introduction about fiber reinforced composites | 2 min |
| 9 | Discussion in groups about the choice of fiber (Use PDF (Pages 1-3) from Appendix D) | 10 min |
| 10 | All in common: Choice of fiber. Including example materials from the MRL. | 5 min |
| 11 | Discussion with the participants about the choice of matrix | 5 min |
| 12 | Introduction about composite structures. Including example materials from the MRL. | 3 min |
| 13 | Discussion in groups about the choice of the material's structure. | 3 min |
| 14 | All in common: Choice of structure. Including example materials from the MRL. Develop and discuss choice between monolithic/sandwich, and the possibilities for the core and inner and outer skins | 15 min |
| 15 | Discussion in groups about the manufacturing of the radome. (Use PDF (Page 4) from Appendix D) | 5 min |
| 16 | All in common: Choice of manufacturing process | 7 min |
| 17 | All in common: Discussion about the sequence of the process and fabrication details. | 7 min |
| 18 | Final remarks | 3 min |
| 19 | Questions | 9 min |

**Figure 2. Sequenced schedule of laboratory exercise (Martinez, 2016)**

# 8 Analysis

The approach of having students develop laboratory exercises as thesis projects can be evaluated on two levels; via a quantitative analysis, where the resources spent having different approaches are evaluated, and via qualitative analysis, where the usefulness of the resulting laboratory exercise itself is discussed along with educational value for the thesis student.

## 8.1 Quantitative analysis

From a resource standpoint, there are three distinct scenarios to look at:

1. Academics will do one BSc thesis supervision, and independently of that develop a laboratory exercise.
2. Academics will do one BSc thesis supervision on the development of a laboratory exercise.

3. Academics will do one BSc thesis supervision on the development of a laboratory exercise, and independently develop a laboratory exercise.

In Table 2, an estimation of supervision workload for different possible outcomes is presented. The numbers are based on professional experience in teaching at Linköping University, and corresponds with existing internal guidelines and norms for supervision workload as well as time spent preparing and developing new laboratory exercises.

**Table 2. Estimated workload for academics for different possible outcomes**

| | ***Independent and high performing student*** | ***Student needs average supervision and performs averagely*** | ***Student needs excessive supervision and performs poorly*** |
|---|---|---|---|
| ***Laboratory exercise developed as thesis project*** | 20-25 hours | 30-50 hours | 80-90 hours |
| ***Laboratory exercise developed separately from thesis project work*** | 60-65 hours | 65-80 hours | 80-90 hours |

Scenario 1 would translate to all outcomes on row 2 in Table 2, scenario 2 would translate to the intersection between “laboratory exercise developed as thesis project” and “independent and high performing student” as well as between “laboratory exercise developed as thesis project” and “student needs average supervision and performs averagely”. Scenario 3 would translate to the intersection between “laboratory exercise developed as thesis project” and “student needs excessive supervision and performs poorly”. In Table 2, the denotion of “high performing student” should be read as “the end result needs no or minor revision”, “performs averagely” should be read as “the end result needs some revision” and “performs poorly” should be read as “the end result needs extensive revision or cannot be used at all”.

This project is evaluated to fall into the category of a “independent and high performing student”, which gives that the estimated time spent from an academic point of view is 20-25 hours.

## 8.2 Qualitative analysis

The work presented by the thesis student is developed as a cross-year group tutoring exercise, and was tested as this, but will be used in education as a traditional laboratory exercise. The resulting laboratory exercise is broad in its scope, spanning from identifying requirements to defining manufacturing processes. This means that the result might lack in depth in some aspects, instead trying to cover as many relevant aspects as possible. The laboratory exercise also shows the connection between different fields of engineering design work adding value to the finished product. Also, the resulting exercise can be seen as a good fit into the educational program with an emphasis on independence and student-initiated information gathering and analysis on applied to a component in an aircraft. The layout of the exercise enables student freedom, something that is in line with higher education in the Nordic countries.

The thesis student emphasized on insights regarding the complexity of engineering design-related problems, communication skills and synthesis/analysis skills in their self-evaluation from the thesis project.

# 9 Discussion, conclusions and implications

This project falls into the least resource consuming of the presented categories: the laboratory exercise done as a thesis project and the thesis project done by an independent and high performing student. This suggests that the proposed approach have a possibility of significantly decrease workload on academics while keeping a high level of educational quality. Looking at table 2, it becomes apparent that the approach of having laboratory exercise development as a thesis project never increases workload comparatively to performing the tasks separately, but using this new approach does not necessarily give significant workload reductions.

While the resulting laboratory exercise would need more depth to fully investigate the issue of designing and manufacturing an aircraft radome, the work that the participants will do gives them an insight into the relationship between geometry, material and processes, and introduces the tasks of connecting requirements to a combination of geometries, materials and processes. It connects to the real-world projects the participants perform in the Aircraft Design Project course, and gives an arena for team work on another scale than in the large design project. It also complements the in depth-approach of the large design project. The presented approach to peer education could be seen as complimentary to the peer collaboration done in the Aircraft Design Project course. The thesis student also expresses learning outcomes similar to those presented in peer education literature.

An interesting aspect is the shift of roles when students are developing material that academics are using in teaching: if made correctly, both views and experiences can be utilized to develop better teaching material. On the other hand, if this shift of roles is not acknowledged, there is a risk that the teaching material becomes unsuitable for the academics and can only be used by students in traditional peer educational settings.

Overall, the process of letting students develop laboratory exercises in thesis projects can be seen to enable the thesis student to develop communication skills as well as integrating knowledge from previous courses, while at the same time giving the possibility for the participating students to have relevant and updated study material to work with. For academics, it can be seen as a possibility to make teaching efficient, and to create a connection between different teaching tasks. While the approach of cross-disciplinary peer education should be further analysed, it shows promise of being fruitful for all involved parts.

# 10 Future work

During spring 2016, a task in a project course for mechanical engineers on bachelor’s level (the final course before writing their bachelor thesis) was to develop and build physical course material for a CDIO course on pre-bachelor’s level in mechanical engineering. This project should be evaluated, to further build knowledge regarding cross-disciplinary peer education.

**Acknowledgement**

The authors thanks Ines Diez Martinez for her work with developing the laboratory exercise. Also, the Vinnova funded Production2030 project “Large Scale Manufacturing in Mixed Materials” have provided funding and served as a confirmation of the need of this type of laboratory exercises.

## Citations and References


Damon, W. (1984). Peer Education: The Untapped Potential. *Journal of Applied Developmental Psychology*, 331-343.

Elata, D., & Garaway, I. (2002). A Creative Introduction to Mechanical Engineering. *International Journal of Engineering Education*, 566-575.

Elken, M., Hovdhaugen, E., & Stensaker, B. (2016). Global rankings in the Nordic region: challenging the identity of research-intensive universities? *Higher Education*, 1-15.

Elverum, C. W., & Welo, T. (2014). The role of early prototypes in concept development: insights from the automotive industry. *CIRP 24.* Milano.

Fabricius, A. H., Mortensen, J., & Haberland, H. (2016). The lure of internationalization: paradoxical discourses of transnational student mobility, linguistic diversity and cross-cultural exchange. *Higher Education*, 1-19.

Fägerlind, I., & Strömqvist (Eds.), G. (2004). *Reforming higher education in the Nordic countries - studies of change in Denmark, Finland, Iceland, Norway and Sweden.* Paris: UNESCO International Institute for Educational Planning.

Hanson, J. M., Trolian, T. L., Paulsen, M. B., & Pascarella, E. T. (2016). Evaluating the influence of peer learning on psychological well-being. *Teaching in Higher Education*, 191-206.

Helgevold, N. (2016). Teaching as creating space for participation - establishing a learning community in diverse classrooms. *Teachers and Teaching: theory and practice*, 315-328.

Henriksson, F., & Johansen, K. (2016). An outlook on multi material body solutions in the automotive industry – possibilities and manufacturing challenges. *SAE World Congress 2016.* Detroit, Michigan, USA.

Jansen, A. (2015). New Teaching Methods in Sports Engineering; How to Speed Up Learning While Having Fun! *Procedia Engineering*, 568-572.

LiU E-Press. (2016, 03 15). *MRL - Material Realisation Laboratory*. Retrieved from MRL - Material Realisation Laboratory: http://www.ep.liu.se/databases/mrl/

Martinez, I. (2016). *Development of an engineering laboratory experiment exploring challenges using lightweight materials - Methodology for the development of a civil aircraft radome.* Linköping, Sweden: Linköping University.

Shiner, M. (1999). Defining peer education. *Journal of Adolescence*, 555-566.

Topping, K. J. (1996). The Effectiveness of Peer Tutoring in Further and Higher Education: A Typology and Review of the Literature. *Higher Education*, 321-345.

Topping, K. J. (2005). Trends in Peer Learning. *Educational Psychology*, 631-645.

Waitz, I. A., & Barrett, E. C. (1997). Integrated Teaching of Experimental and Communication Skills to Undergraduate Aerospace Engineering Students. *Journal of Engineering Education*, 255-262.

Walker, S. A., & Avis, M. (1999). Common reasons why peer education fails. *Journal of Adolescence*, 573-577.

Wever, R., & Christiaans, H. (2010). Impact of Bachelor Research Projects by Design Students. *DS 62: Proceedings of E&PDE 2010, the 12th International Conference on Engineering and Product Design Education-When Design Education and Design Research meet...,* . Trondheim, Norway: Design Society.

Wever, R., & de Eyto, A. (2013). Teaching Strategic and Sustainable Design. *Proceedings of EcoDesign 2013.* Jeju, South Korea.

Willemsen, L. (2012). English Academic Writing by Dutch Engineering Studends. *Van Schools tot Scriptie, een colloquium over universitair taalvaardigheidonderwijs* (pp. 139-152). Smakman & Willemsen.