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MASTER STUDENTS LEARNING TRIZ AT THE UNIVERSITY: PAST EXPERIENCES, FUTURE PLANS, AND BEST PRACTICES

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Abstract

Creating an efficient learning environment for TRIZ at a university is far from trivial. Although the TRIZ-tools for solving problems can appear simple at a glance, applying them to real world problems by beginners is not. In this paper we share our experiences teaching and developing a university course in TRIZ for Master students with different Engineering backgrounds. The syllabus of the course is presented, student results and feedback are analyzed, and plans for future course development are discussed.

Keywords: TRIZ Education, University, Master students, Learning environment

1. Introduction

1.1. Very nice and interesting, thank you, but what have I actually learnt?

Problem solving is central to life. Acquiring practical problem solving skills is therefore essential – in particular in the context of engineering student education. Engineering students face and solve problems continuously throughout their education, but the problem solving process itself is seldom the focus of attention. A course devoted to problem solving is an important opportunity for students to orient themselves of alternative ways of solving problems and to challenge their own approaches.

The theory of inventive problem solving (TRIZ) is, in this respect, a suitable topic. It is a systematic approach to problem solving that provokes the user to think creatively about a problem [1]. TRIZ offers a set of objective rules, or models, for the user to map the specific problem on more general problems, and from these, abstract conceptual solutions that can be turned into specific solutions to the problem at hand [2,3]. With a balanced attention to both problem definition and problem solving – and with an ideal final outcome in mind – TRIZ holds the promise of guiding the user into a non-biased state-of-mind and through a process that leads to solutions that are unique, simple and elegant [4]. Given these promises, TRIZ is a subject that should appeal to engineering students – and initially it does.

A challenge we have identified, however, offering a university course on the subject to Master students, is to leave the students with a confidence in TRIZ as an immediately applicable, practical resource for the future – not only a theoretical curiosity. This challenge is well-known and has been linked to pedagogics, often with the aim of promoting new ways of teaching TRIZ; "old-way" training, for example, have been argued to lead to "fuzzy understanding" and "insurmountable barriers" to practical application [5]. The "instructor effect" – the dependence on the learning outcome on highly experienced and skilled instructors – is another problem that has been put forward [6]. The way forward, we believe, is not so much to identify the "right teaching method" or hire the most skilled TRIZ instructor, but to develop a flexible and dynamical learning environment that serves the education goals.

TRIZ education at universities is not a new phenomenon, but has in recent years become more visible in what has been dubbed a "world of consultants" [7]. An excellent introduction to the challenges of TRIZ education and the important role of universities is provided by Wits *et al.* in their documentation of a comprehensive (140h) and intense TRIZ course for Master students at the University of Twente [8]. Overall, the growing substance of literature on TRIZ projects and education carried out at universities helps to make the pros and cons, and the educational aspects of TRIZ, more transparent. Previous studies address, for example, the impact of TRIZ on innovative thinking problem solving skills of university students [9–16] and the dependence of the learning outcomes on the specific learning environment. The latter include the effect of format (lectures, tutorials, projects) [7], content (academic, best practice, or real-life problems) [17], the use of software or other pedagogical tools [6,18,19], and the importance of student-student and student-teacher interactions [7].

In this work we present and discuss the learning environment for TRIZ, with respect to the second topic, in the specific environment of our university course. What was our starting point, what have we learnt during the two semesters that we have been in charge of the course, how have we modified the course accordingly, and what are our plans for the future? Our aim is not to provide "*the*" solution, but to contribute to the discussion of how to create efficient learning environments for TRIZ at the university within a given context. The essence is very well captured by Cavallucci et al. [6] to *"bring engineering students to a level of TRIZ understanding that will enable them to use it in their future industrial experiences"* or elsewhere.

2. Course background

2.1. Why and how is a Physics department offering a TRIZ-course?

The TRIZ course *"TIF185 Creative problem solving in Engineering"* comprises 7.5 ECTS (European Credit Transfer and Accumulation System) merit points, where one year of full-time studies is equivalent to 60 ECTS. Our course corresponds to 5 weeks of full-time studies, or approximately 200 hours, spread out over a formal study period that extends from the start of November to mid-January. This is a rather ambitious scope, since most TRIZ training worldwide is limited to 20 hours or less according to a survey by the European TRIZ association [20]. However, as detailed further down, a majority of the work by the students occurs out-of-class.

The course attracts *ca.* 15 Master students every year. Characteristic is that we have a mix of students from different countries and from different programs and relatively few teacher-lead learning activities. This is partly due to budget restrictions, but also based on the idea that a final project should make up a considerable part of the course.

The course was first introduced in 2008 under the name *"Special topics in applied physics"*. The intention of the course was to offer students a new topic each year, not covered by the standard curriculum, but TRIZ remained the subject of the course and the name was changed. The authors of this paper took over responsibility for the course in 2014. We each have roughly 80 hours of formal TRIZ training from attending various workshops offered by consultants in the field; *Oxford creativity*, *The International TRIZ Association (MATRIZ)*, and *The TRIZ group*. As our training is relatively modest, we are by now means TRIZ experts, which adds to the challenges of designing and running the present course.

With the course we inherited a learning environment essentially structured around a set of *lectures/workshops*, which introduce the basics of TRIZ, an extended *team-based project work*, and *a written final exam*. The project constitutes approximately 60% of the total course work, reflected in the grading of the students' work (60% Project, 40% Exam). As mentioned, the majority of the work by the students occurs out-of-class, in the form of team-based projects.

Our first year (2014), we decided to keep the changes to a minimum, including the course book *Innovation on Demand* [3], but to carefully monitor the course work for future developments. The in-class activities of the course 2014 consisted of approximately 8 hours of lectures and 12 hours of practical exercises (Table 1).

In preparation for the class of 2015 we made a number of changes to improve the learning environment based on student feedback and our own experiences from 2014. The hours in-class remained effectively unchanged (not counting a few additional hours for mini-exams, project information, and supervision), but were now formally distributed as 4 hours of lectures and 16 hours of Workshops (Table 1).

Table 1

Overview of in-class activities during 2014 and 2015

2014		**2015**	
W	**Activities**	**W**	**Activities**
1	Lecture 1 (2h) *Basic Theory and Tools*	1	Lecture 1 (4h) *Basic Theory and Tools*
1	Lecture 2 (2h) *SU-Field*	1	Workshop 1 (4h) *Basic Tools*
1	Exercise 1 (4h) *Basic tools*	2	Workshop 2 (4h) *SU-Fields, Creax software*
2	Lecture 3 (2h) *ARIZ*	2	Mini exam 1 (2h) *Covering WS1 and WS2*
2	Exercise 2 (4h) *Creax software*	2	Project information (1h) *Project initiation*
3	Lecture 4 (2h) *ARIZ, Project initiation*	3	Workshop 3 (4h) *ARIZ*
3	Exercise 3 (4h) *ARIZ*	3	Workshop 4 (4h) *Trends of evolution, S-curves*
		4	Mini exam 2 (2h) *Covering WS2 and WS3*
		6	Mid-project presentations (2h)
7	Project presentations (2h)	7	Project presentations (2h)
	Break for Christmas		*Break for Christmas*
10	Final exam (4h)	10	Final exam (4h)
	Total in-class activities = 26 h		**Total in-class activities = 33 h**

W = Course week. Number of in-class hours (h): 1h = 45 minute activity + 15 min break. WS = Workshop. Basic theory and tools: 9-Windows, Function Analysis, Contradictions, Ideality.

3. Course development

In this section we review the main elements of the 2014 syllabus and the changes made for 2015. We also present some trends observed in a general course survey that students complete for every course. The limited scope of this paper excludes an exhaustive presentation of details; instead, the focus is the general lines of development.

3.1. From Lectures and Exercises to Workshops

The most important observation or realization in the 2014 edition of the course was that too much time was concerned with teaching and not with learning. Our impression was that students were left too passive, in particular: *i)* listening to lectures on TRIZ, although perfectly adequate, are not efficient when it comes to real problem solving. It is our opinion that lectures on TRIZ often provide a false sensation of understanding. *ii)* The lack of formative assessment during the course allowed the students to stay too long in the “false” sensation that they understood the different methods from the lectures. However, *the devil is in the details* and if the methods are not really applied to real problems by the students themselves, not much is really learned.

For the exercises, we realized that: *i)* Exercise 1 contained too much substance, it was not necessary to have a full exercise on the Creax software, and *ii)* the present course would benefit from additional literature – complementary to the main literature of the course.

The number of hours for lectures and exercises, relative the total number of hours students are expected to invest, is very small in our course in comparison with other TRIZ courses [6,7,21], but the distribution of hours between lectures and practical sessions is similar, and the reference courses are not all exclusively limited to TRIZ. The number of in-class hours in our course, however, is difficult to increase based on budget restrictions due to the relatively few students enrolled in the course. Modifications are therefore focused towards an optimal use of hours.

In 2015 we reduced the number of formal lectures to one 4-hour introduction lecture, where the general concepts and basic tools of TRIZ (9-windows, Functional Analysis, The Contradiction matrix, and the Ideality principle) were introduced. The content of the remaining lectures and the practical exercises of 2014 were integrated into workshops more focused on applied problem solving. By reducing the time spent on the software we were able to devote almost a full workshop to SU-field analysis.

3.2. Clarifying Project Instructions and Expectations

The challenges connected to the project work are to prepare the students adequately for the task, to find problems at a suitable level, and provide sufficient support during the problem solving process.

Students were assigned to project groups of 3-4 with a good mix of educational and cultural background. Despite some initial adaptation and rare problems with the group dynamics, the students appreciated the opportunity to work in the mixed groups. A new development for 2014 was to let the students tackle real problems posted by companies at an innovation challenge site [22]. Each group was allowed to select one out of a pool of five preselected problems. The task was threefold: *1)* Analyze the problem using TRIZ principles, *2*) suggest solutions to relevant system conflicts, and *3)* predict the evolution of the technology.

The realistic problems gave an edge to the problem solving process, but were in some cases overwhelming and lead to outcomes of varying quality. Students were encouraged not to jump to an obvious solution, but we still experienced that some groups “locked into” a given solution early and were paying too careful attention to the opinion of domain authorities within the group. The students themselves expressed that information about the project came too late – not until after the final lecture – and were concerned about the structure of the project being unclear.

The project work was carried out entirely out-of-class with the exception of a 30 min supervision meeting with each of the five groups halfway through the projects. The meetings were setup to ensure progress and provide a feedback opportunity. It was not immediately clear if these meetings had a positive impact on the project work.

List of project topics 2014
Transformational Packaging Solutions for Temperature Sensitive Products
Reducing Galactic Cosmic Rays to Enable Long Duration Deep Space Human Exploration
The Next In-Car User Experience

List of project topics 2015
Anti/de-icing Solutions for Distribution Networks
High-speed, Large Scale Controlled Separation of Water and Solids
Identification Coding on Medical Instruments
New Ways to Kill/Trap/Repel Insect Pests in the House

In 2015, the students were divided into groups and informed about the project already after the second workshop. Expectations were communicated more clearly by providing a template, which structured the project into five parts: *1)* Problem statement, *2)* Analysis of conflicts, *3)* Analysis of resources, *4)* Development of conceptual solutions and *5)* Evolution of technology. Each part was supported by additional information about expectations and suggestions of useful TRIZ tools.

The early formation of project groups and template had several positive impacts; *i)* the group members were required to work together in the remaining two workshops to get to know each other, *ii)* the groups could start the planning of the projects earlier, and *iii)* the project outcomes (reports and presentations) were more uniform and of better quality. The feedback opportunity halfway through the projects was in 2015 complemented by a full in-class feedback session, where each group was able to receive and give their peers feedback on the project standings based on short 10 min presentations.

3.3. From a Final Exam to Formative Assessments

In 2014, students were graded based on the project work (60%) and an open-book Exam at the very end of the course (40%). All 15 students completed the course with a pass and the average grade (on a scale of 3-5) was 3.9. The average student score on the project was 13.2 (out of 20) and for the Exam 13.9 (out of 18).

For the class of 2015 we introduced two voluntary written mini-exams, as formative assessments at a much earlier stage, in addition to the final exam and project evaluation. All students were encouraged to take the mini-exams and were awarded a bonus point for a pass, which was added to the score of the final exam. Each mini-exam provided the students an opportunity to demonstrate proper use of the TRIZ tools introduced so far. We can see that this improved the learning in two ways. Firstly, the students were forced to do some serious studying to prepare for the mini-exams and secondly we received some important feedback on what the students found difficult. The mini-exams were organized as two-hour activities, where the first hour was assigned for the exam and the second hour was used for a collective reflective analysis of the exam.

The 14 students of the class of 2015 completed the course with an average grade of 4.2 out of 5. The improvement in results was due to improved scores on the final exam 16.9 out of 20 (including two bonus points). The average project results (13.5 out of 20), however, were similar to the previous year. The scoring is subjective and to some extent difficult to judge, but our overall impression is that the students benefited from the formative assessment and that project outcomes were improved. Still, the project outcomes, *i.e.* the ability of the students to apply TRIZ to solve realistic problems, could (in our opinion) improve much further with the appropriate measures.

3.4. Student Surveys Direct Future Development

A summary of the course evaluations from 2014 and 2015 is shown in Table 2. The survey was completed by 7 (47%) of the students in 2014 and 12 (86%)! of the students in 2015. The difference in answer frequency can to some extent be explained by the fact that we in 2014, at the end of the in-class activities and in addition to this formalized University course survey, conducted a student survey of our own (unfortunately this was not done 2015). This could have decreased some student's motivation to answer a second survey. Although one should not over-interpret the data, the results are both encouraging and surprising at the same time. It is encouraging to see the consistent improvement in the rating of the individual statements, while at the same time surprising that the total grade of the course has not changed.

Our analysis is that despite the improved quality of the various elements of the course the students were still not completely convinced of the use of the course and whether they had actually learned something useful or not. This is indeed also our experience from different workshops by professional companies. Insufficient feedback on the project work is one of the things that need to be improved according to comments by individual students in connection with the survey of 2015. In addition, we believe that students are not yet given adequate opportunity to experience that they can successfully apply the TRIZ tools to real problems.

Table 2

Student survey results from 2014 and 2015

Survey statements (rating 0-5, where 5 = total agreement)	**2014**	**2015**
The course structure is appropriate in order to reach the learning outcomes	3.43	4.42
The teaching worked well	4.14	4.42
The course literature supported the learning	3.71	4.50
The assessment tested whether I had reached the learning outcomes	4.00	4.08
The course administration worked well	4.29	4.67
Sum	**19.57**	**22.09**
Overall satisfaction with the course	**3.86**	**3.83**

Selected student responses:

"Feedback on the work could be better. After the first presentation almost no feedback was given."

"A meeting with the teachers (is required) earlier in the process for the project work. If things have to be changed it is quite a rush otherwise."

"Will what I've learned from this course really help me in the future? Is this topic really that important? I'm not sure yet, but maybe."

4. Conclusions and Future Development

Course development is like peeling an onion. Once one level of problems has been addressed a new level is exposed. Based on the previous discussion, we have several lines of developments in pipeline for the course.

A general question is how we should optimize the student learning and make better use of both the few in-class activities and more abundant out-of-class activities (*ca.* 160 hours formally distributed over 8 weeks). A particularly useful pedagogical method to address this question is the principle of Constructive Alignment [23] where, in short, a set of intended learning outcomes (ILO), and the methods to assess these, are defined, after which a suitable ensemble of teaching and learning activities are selected to bridge the ILO with the assessments. Such a recalibration of the course has yet to be performed.

On a more detailed level, the next step is to improve the students' skill to independently apply TRIZ to solve real problems. We have several ideas how to facilitate this; the first idea is to compile a considerable set of pedagogical exercises, many with solutions, which are possible to solve without domain knowledge and without the guidance of a teacher. This provides a routine for how to apply the methods on a variety of problems and, not the least, confidence in the methods. Different types of problems (academic, best practice, and real-world problems) serve different purpose of illustrating methods, motivating students *etc.*, which should be taken into account [17]. As suggested elsewhere, a centralized (web-based and open) database with pedagogical TRIZ problems would be an important asset [5]. However, the willingness to make use of, but not contribute to, such centralized information appears to represent a paradox [20].

The second idea is to improve the efficiency of learning before and after the workshops by helping the students prepare in advance, both in terms of skill and mind-set. A list of recommended reading is not a sufficient complement to in-class activities. Suitable pre- and post-workshop tasks should encourage active engagement, individual reflections, and lead to a deeper understanding of the material. Such improvements would also allow the workshops to focus more on hands-on problem solving and cooperative learning/reflections [7], in place of establishing the framework. The idea is closely connected to, and can take advantage of, the principle of constructive alignment and the concept of a *Flipped Classroom* [24].

The third idea relates to the development of the project part of the course, but it is not obvious how to proceed. One possibility is to integrate the projects more closely with the workshops, applying the tools directly within the project [16], but drawbacks are that the students have not yet reached a level where they are comfortable with the tools and are not allowed to critically reflect over the appropriate tools for their projects. To practice TRIZ on authentic problems, without knowing the outcome beforehand, is arguably an essential part of exploring and learning the different tools, but also very challenging. The uniqueness of the problem requires a more experienced user and makes it more difficult to turn to the teacher or literature for help. For both the teacher and student it can be an intimidating experience; the teacher has little control over the outcome and shares a fear of failure with the student. What if? The different and varying activities of the course require the teacher to take different, appropriate roles, depending on the activity – in particular to be prepared to discover authentic problems together with the students as experienced colleagues [7], which takes some practice.

An alternative to a single, large project is to replace it with one or several smaller individual and one intermediate sized team project. The smaller projects could be valuable out-of-class activities to prepare the students for the larger projects and allow for mistakes, *i.e.* not to put all eggs in one basket. By involving the student in the choice of topic of the small project, these could offer more personalized and varied learning opportunities. Small projects could, for example, involve the analysis of patents [25] or trends for systems of particular interest for the student. The project outcome could be appropriate for pair-wise peer-review among the students to facilitate cooperative learning.

To conclude, it is obvious for us, when researching for and writing this paper, that we are in part rediscovering well-known problems within the community that could partly have been foreseen by an earlier awareness and improved connectivity with the field. However, there is clearly also a clear need for further exchange and dialogue about appropriate activities and environments for learning TRIZ at universities, to which we hope to contribute with this and future work.

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References

[1] Dew J. "TRIZ: A Creative Breeze for Quality Professionals", Qual. Prog. 39 (2006) pp. 44-51.
[2] Altshuller G. "And Suddenly the Inventor Appeared", Technical Innovation Center, Inc., 2001.
[3] Fey V., Rivin E. "Innovation on Demand", Cambridge University Press, 2005.
[4] Gadd K. "TRIZ for Engineers", Wiley, 2011.
[5] Orloff M.A. "Modern TRIZ: A Practical Course with EASyTRIZ Technology", Springer-Verlag, 2012.
[6] Cavallucci D., Oget D. "On the efficiency of teaching TRIZ: Experiences in a French engineering School", Int. J. Eng. Educ. 29 (2013) pp. 304-317.
[7] Choulier D., Weite P. "From TRIZ to technical creativity teaching", International Conference on Engineering and Product Design Education, 6-7 September, 2012, Antwerp, Belgium.
[8] Wits W.W., Vaneker T.H.J., Souchkov V., "Full Immersion TRIZ in Education", (2010) pp. 269–276.
[9] Ogot M., Okudan G. "Systematic creativity methods in engineering education: a learning styles perspective", Int. J. Eng. Educ. 22 (2007) pp. 566–576.
[10] Belski I. "TRIZ course enhances thinking and problem solving skills of engineering students", Procedia Eng. 9 (2011) pp. 450–460.
[11] Genco N., Hölttä-Otto K., Seepersad C.C. "An experimental investigation of the innovation capabilities of undergraduate engineering students", J. Eng. Educ. 101 (2012) pp. 60–81.
[12] Belski I., Baglin J., Harlim J. "Teaching TRIZ at university: A longitudinal study", Int. J. Eng. Educ. 29 (2013) pp. 346–354.
[13] Belski I., Belski I. "Application of TRIZ in improving the creativity of engineering experts", TRIZ Futur. Conf. 2013. 131 (2013) pp. 67–72.
[14] Livotov P. "Measuring Motivation and Innovation Skills in Advanced Course in New Product Development and Inventive Problem Solving with TRIZ for Mechanical Engineering Students", Procedia Eng. 131 (2015) pp. 767–775.
[15] Chang Y.S., Chien Y.H., Yu K.C., Chu Y.H., Chen M.Y.C. "Effect of TRIZ on the creativity of engineering students", Think. Ski. Creat. 19 (2016) pp. 112–122.
[16] Sheng I.L.S., How K.B., Hoo T.E., "Teaching, Learning & Applying TRIZ in University", in Conference proceedings TRIZfest-2015, Sept. 10-12, 2015, Seoul, South Korea.
[17] Albers A., Lohmeyer Q., Schmalenbach H. "Triz-box in Design Education - a Study on Supporting Creativity", International Conference on Engineering and Product Design Education, 8-9 September, 2011, London, United Kingdom.
[18] Becattini N., Borgianni Y., Cascini G., Rotini F. "A TRIZ-based CAI Framework to guide Engineering Students towards a Broad-spectrum Investigation of Inventive Technical Problems", Int. J. Eng. Educ. 29 (2013) pp. 318–333.

[19] Cascini G., Saliminamin S., Parvin M., Pahlavani F. "OTSM-TRIZ Games: Enhancing Creativity of Engineering Students", Procedia Eng. 131 (2015) pp. 711–720.

[20] Cavallucci D. "World Wide status of TRIZ perceptions and uses a survey of results", A Report from the European TRIZ Assoc. (2009), Timisoara, Romania.

[21] Chechurin L. "Systematic Creativity - TRIZ Basics 3 ECTS credits", www.lut.fi/documents/27578/148066/Basic+TRIZ/2c113b9f-eefa-4965-a80c-5fb87a4145a3 (accessed July 11, 2016).

[22] Innocentive, www.innocentive.com/ar/challenge/browse (accessed July 11, 2016).

[23] Biggs J., Tang C. "Teaching for Quality Learning at University", McGraw-Hill and Open University Press, 2011.

[24] Mazur E. "Peer Instruction: A User’s Manual Series in Educational Innovation", Prentice Hall, 1997.

[25] Ishihama M. "Training students on the TRIZ method using a patent database", Int. J. Technol. Manag. 25 (2003) pp. 568–578.