Adaption and evolution of a first year design project week course-From Germany to the United States to Mongolia

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First year design projects are needed to introduce students early in their studies to design work, prepare students for requirements of industry, and give students a positive perspective on their upcoming coursework during their degree program. Introduction to German Engineering (IGE) fulfills these purposes along with promoting interdisciplinary work and professional skills, especially the development of team competencies integrated within the subject-related process of problem solving. It is a first year course taught to introduce students to the German engineering design process and project work in groups. It was developed in 1998 at the Technische Universität Darmstadt Mechanical and Process Engineering Department in cooperation with the Center for Educational Development at TU Darmstadt. Through this collaboration, students are also taught professional skills such as group management, team work skills, and communication within the context and integration of the subject. IGE was then expanded to an international experience with two participating American universities, South Dakota School of Mines and Technology and Virginia Tech. It has most recently been adapted and taught at a Mongolian University, German Mongolian Institute for Resources and Technology. This paper will discuss the major aspects of the course, in particular, the history and development of the course, the didactic concept and support system, the expansion of the original course to an interdisciplinary, international course, adaptions of the course for GMIT, general success of the course in all of its forms, and future developments of the course.

Introduction

As project work is becoming more prevalent in the work place, students need the skills necessary such as teamwork and communication to become successful professionals upon graduation, especially in the field of engineering. They need to be able to not just work with colleagues in their field but also professionals in different disciplines to develop well-rounded, unique solutions to problems. Technical competence has previously been defined as a high level of motivation, use of intelligence to solve problems and make decisions, teamwork, management and leadership of others, communication, planning and management of a project and resources, innovation, and a strategic view of the larger picture of the project[1,2]. These competencies, along with technical knowledge and experience, have been linked to future professional experience and better final design projects[2,3].

To meet these requirements involving project work, higher education institutions have two learning approaches, problem based learning (PBL) and project oriented learning (POL). PBL has been previously defined as learning that is student-centered in small groups facilitated by the teacher and organized around defined problems. The problem is the initial and focal point of the learning process. POL is complex problem-based in the context of a team working together to reach a project goal that is typically highly challenging and includes individual and group activities, discussions, and a writing process. POL additionally teaches project management and teamwork competencies[4]. Mills and Treagust[5] summarized the main differences of PBL and POL. Some of the major differences they observed included project tasks are closer to professional work and thus use a longer period of time in comparison to PBL, POL is more focused on application of knowledge whereas PBL is more focused on acquisition of knowledge, in POL, time and resource management is very important along with task and role differentiation, and more self-motivation and direction is needed in POL in comparison to PBL[5].

Discipline-based project courses have been shown to increase retention rates[6,7,8] and intellectual development[9]. Mahendran[10] reported that students not only increased their technical knowledge, knowledge of the concepts in the projects, and knowledge of the design process but also increased their technical writing and research skills, and that students preferred having projects within a course.

Our Introduction to German Engineering course fulfills these above purposes of POL and PBL by integrating team and communication competencies within the context of a subject-related design process. This course aims to introduce to first year students to the design process by solving a societal related, complex problem in large, and more recently interdisciplinary, groups. The development, adaptations, extensions, success, and future of this course will be discussed in detail.

History and development of Introduction to German Engineering (IGE)

Introduction to German Engineering (IGE refers to the general concept and IGE-GER refers to the original course to differentiate it from the future adaptations of the course) was originally developed in 1998 at the Technische Universität Darmstadt (TU Darmstadt) as a project week in collaboration with the Center for Educational Development. IGE-GER was developed as and continues to be an intensive, immersive, one-week design project course for first year engineering students. The purpose of IGE-GER is multi-faceted in developing the technical expertise and professional skills of students along with socialization and networking, providing a future perspective, and development of their self-perception of confidence in their respective fields.

The Mechanical and Process Engineering Department at TU Darmstadt developed IGE-GER due to several concerns and deficits shown through a departmental evaluation in 1997[11,12]. These included industry demands that graduates be technically knowledgeable but also are proficient in professional and social skills, and faculty members were concerned especially about the dropout rates for engineering (approximately 40% at this time)[11,12]. It has been suggested that the sensitive time for dropping out of engineering programs occurs during or after the first year of study possibly due to lack of interest in science or poor teaching practices[12,13,14]. Also, recommendations made in the European "Bologna Process" led to the decision for a project-based course concept[11]. These concerns led to the development of an innovative project-based course for first-year students that introduces students to German Engineering as well as integrates training of team competencies and working techniques[11,12].

Learning objectives of IGE-GER

Through the project, students have the opportunity to glimpse the overall sense of a future industrial group project and see how their coursework (present and future) is related and relevant to their future professional careers. IGE begins to prepare students to meet the industrial needs of technical capabilities coupled with professional and social skills and hopefully further motivate students in their chosen field of study and help the students perceive themselves as confident and competent representatives of their field[11,12,15,16,17].

The task is designed to be open ended, complex, challenging, and similar to a team-oriented industrial project to give students a better perspective on their coursework and why it is important to learn all the basic engineering and technical subjects in their respective field such as mathematics, physics, chemistry, transport phenomena, kinetics, reactor design, process control, and their use in design. In addition to perspective on their coursework and its importance, they should increase their knowledge of theory and application of theory through practice. Because the task is very challenging, the students also learn what they do not know and why it is important, but care is taken in writing the task to not overwhelm the students and cause them to quit due to the complexity of the task and lack of knowledge. They have to solve the task under restrictions such as having too little time and too little task-specific knowledge to solve it perfectly. As a result, the students have to work together and make basic decisions as a team, set priorities in task processing, and at the end support the team's decision-making and market the concept to a jury panel and their peers[11,12,15,16,17].

Additionally to developing an awareness of the design process, a future career perspective, and the importance of their coursework, the students need to work in a team to successfully finish the project. Through this cooperation, the students gain competency in team skills such as chairmanship, visualization, respectful behavior, efficient discussion sessions and communication, and working techniques (optimal techniques related to the problem solving phase) that will further aid the students in their studies and work life. Throughout the project week, the students also increase networking with their colleagues, professors, and academic staff[11,12,15,16,17].

German engineering design process

Students are given a real life example, open-ended, complex, typically societal related, design task to solve in teams of 10-12 students using the German engineering approach[18,19]. This approach refers to the engineering in German speaking countries. It is a unique approach that employs a methodological, linear process, especially for these open-ended, complex, "real-life" tasks. The following description follows the "Construction Method" (Konstruktionsmethodik), which has been developed by Pahl and Beitz at TU Darmstadt and is shown in Figure 1[19]. The Construction Method breaks the design process into three levels: functional, physics, and constructional. Before entering the functional level, the open-ended task must be further defined and clarified. Once specified, the functions and their corresponding structures and relations are defined in order to meet the requirements. The corresponding principles of physics are applied in order to perform the required function, which leads to the construction level where different machinery and apparatus are proposed to perform these principles. Through the three level process, this complex task is broken down into realizable (or sub-task) modules with several solutions for each sub-module. The possible combinations are then evaluated for the best overall solution. Preliminary design may involve or ask further questions that were not initially proposed and bring the design back to the first step thus making it an iterative process until a final solution is produced[18,19]. The fourth phase is not completed by students in the IGE courses but is sometimes realized by students in advanced design projects towards the end of their studies supported by engineering faculty and sometimes supported and funded by industry. In comparison, the American engineering approach is typically taught as a five-step process by first drawing a boundary around a given task then define the given information, what is to be found or solved, which equations to use, diagram the problem, and then determine the solution. In French engineering, a problem is typically solved from first principles[20].

Following the German approach of methodological principle of design, the general requirements for the task are that it must be a challenging, complex, and an open-ended, real-life problem, which requires specialization and division of labor within the group. The task has to be within an engineering and technical subject with no standard solution, have multiple possible concepts and solutions that conflict between time, available resources, and completion within the given timeframe so that the team has to make decisions regarding which features to further develop than others, be societally relevant, and motivate the students.

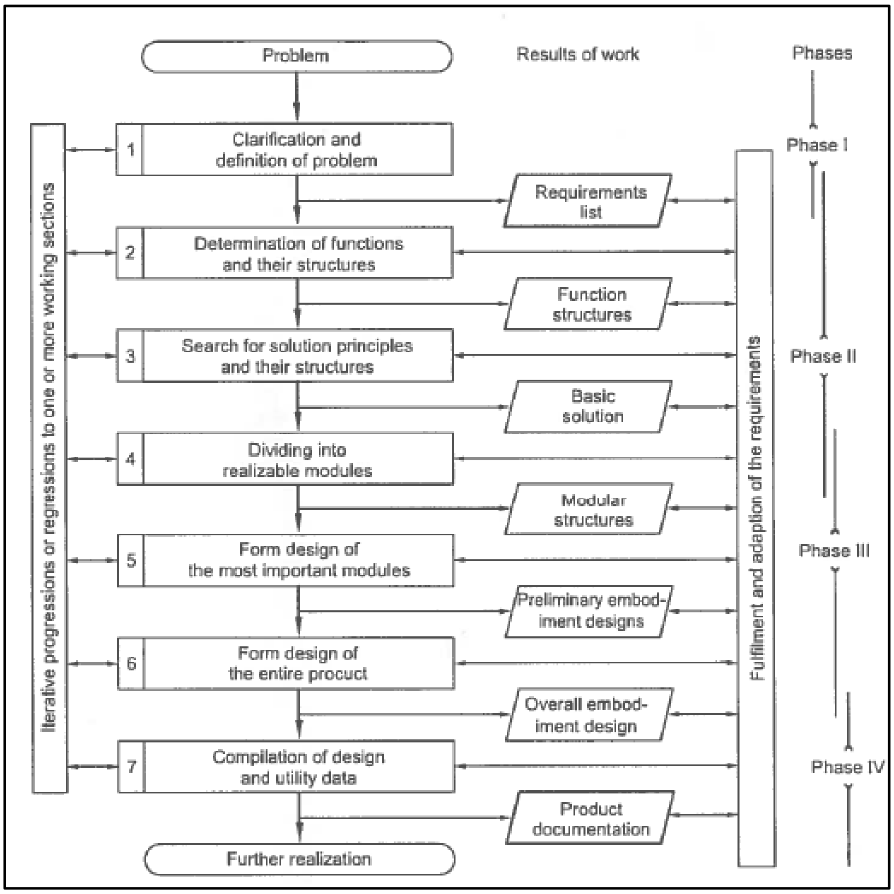

Figure 1: Methodology of German Engineering[18,19].

Examples of past design projects include “Construction of a modular coffee machine system for restaurants of various sizes,” “Design of a very large barbeque grill” (winning design constructed and used successfully), “The use of water absorption on zeolites for cooling,” “An automatic hair cleaning apparatus,” and “An un-manned system for destruction of illegal poppy plants.”

Instructional approach: Didactic concept and support system

To meet all of these goals in the project week course, it is taught in collaboration with the Center for Educational Development at TU-Darmstadt and has a unique approach for instruction[11,12,15,16,17,21]. Student groups are introduced to the task and taught working techniques at the beginning of the week and have exactly one week (working hours) to finish the design task.

The didactic concept of IGE-GER has been previously elaborated and well documented[11,12,15,16,17,21], but is continually evolving to improve the practice. Following the approach of project-oriented and problem-based explorative learning, the students should learn self-organization and to take full responsibility for their process of problem solving as well as for their team process. Without any support, the project teams of first-year students would be overwhelmed with the challenging task in this setting. The high expectations of the design task are kept with the addition of a fine-tuned support system as shown in Figure 2[17]. It is differentiated into team assisted and subject assisted learning. This support group includes two advisors, a help desk, and consultation with experts.

The two advisors are a team advisor (team assisted learning) and a technical advisor (subject assisted learning). These two advisors build a support team, which alternatingly accompanies two project teams for the entire project week. The *technical advisors* (also referred to as the *subject advisors*) are scientific staff of the engineering faculty and follow the didactic principle of minimum help[22]. Shortly, this principle refers to help by empowering the project teams to self-help through giving as minimum help as possible and only as much that is needed or necessary. The technical advisor accompanies the process of problem solving and generally does not explicitly help the group, but is thinking ahead in the process and if they see the group is moving off topic and/or is not moving through the design process as needed to solve the given task, the technical advisor may step in to offer feedback on the group's progress and/or solutions and offer general strategic help or offer content-related strategic help, typically later in the week.

Whereas the technical advisor has a more passive role in the group, the team advisor has a more active role. The *team advisors* are mostly students of psychology and pedagogy who have been intensively trained by the Center for Educational Development for two terms. This concept has been previously documented[11,12,15,16,17,21]. In 2010 Eger and her team received university-wide recognition for interdisciplinary teaching at TU Darmstadt for this process. The team advisors are responsible for establishing standards and criteria of behavior modeled by professional teams in industry. Afterwards, the team advisors support team building, development of team competencies (including discussion behavior, moderation behavior, visualization techniques, and problem solving behavior) as well as further working techniques for the teams fitting to the specific phase of problem solving the team is in. This is done by observing the group and their interactions. After observation, the team advisor brings the group together and opens a structured feedback session including self-reflection, peer-reflection, and final feedback of the team advisor. Periodically throughout the day, the team advisors continue to have these conversations with the group to keep increasing their awareness of their interactions with each other and increasing their team, communication, and social skills in order to increase their success as a group in solving their complex design task. To summarize, the students are given behavior-based training in team competencies in addition to working techniques, which is integrated into the process of problem solving. They have the opportunity to enhance their individual performances as well as their collective performance as a team and experience in real-time how better teamwork improves the process of problem solving[16,17].

There is a typical dynamic of team-assisted and subject assisted learning. At the beginning of the project, there is more intensive team assisted learning which begins to fade-out at the middle to end of the week, as the subject assisted learning is fading-in as the teams delve deeper into the design process and develop a final solution to their task. The advisors, both technical and team, have a *support staff* for additional technical and didactical expertise if needed[16,17].

The groups also have access to a *help desk* for any scientific research inquiries. The help desk is populated by upperclassmen and academic staff that have participated in the simulation of the task with the technical and team advisors and are fully knowledgeable in the background of the task. The students must have specific questions to ask the help desk. For example, the groups cannot ask whether they think an idea is feasible or not. The support of the help desk is also oriented by the principle of minimum help, but begin at a higher level of support compared to the technical advisors[16,17,22].

During the middle of the project week, the student groups have the chance to schedule appointments with a *panel of experts*, typically the professors in the department, to discuss their solutions or consult for any number of problems they may be facing. These "expert-interviews" are limited in time (approximately 10-15 minutes for one expert interview, in whole approximately 2-3 hours for the entirety of the expert interviews) which forces the groups to prepare beforehand either a list of questions or bullet points to discuss with their chosen expert(s) to fully utilize the time allowed[16,17]. A more detailed description of the concept is in preparation by the authors.

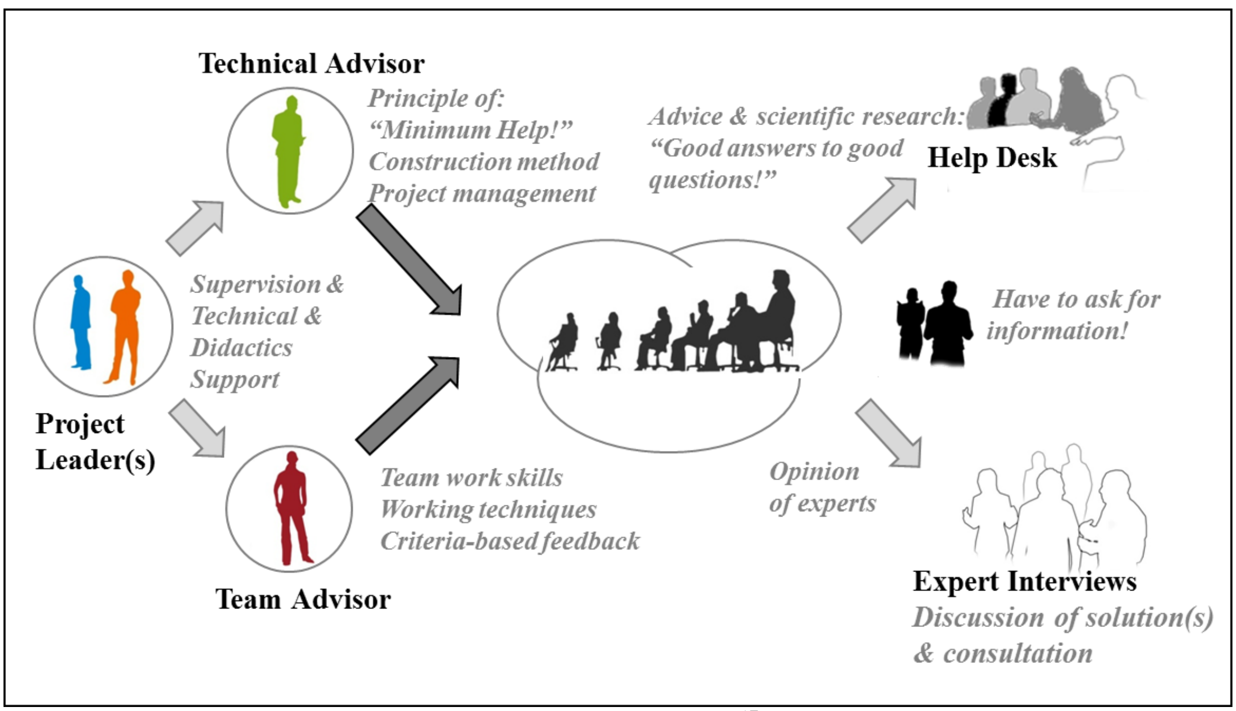

Figure 2: Support system for student groups during IGE-GER[17].

As mentioned previously, the two advisors co-advise two teams simultaneously with each team alternating between team- and subject-learning. The teams are introduced to each other and the task Monday morning. Students usually do not know each other before project week begins. After introduction to the task, the team and technical advisors hold a kick-off meeting with both of their teams together followed by team building. Typically, the teams perform task analysis Monday afternoon followed by goal setting Tuesday morning where they develop a concept of the basics and overall solution. Wednesday morning consists of the expert interviews followed by developing a preliminary draft Wednesday afternoon. On Thursday, the teams continue the refine and integrate their draft and must be completely finished by the end of Friday. Twice a day, the two advisors meet to review and discuss the previous half-day of work and to discuss any problems that may have come up before switching groups.

The following Wednesday, the student teams present their final designs to a judging panel. The judging panel typically includes professors, academic staff, and industry representatives depending on the project that year. The best design receives a "prize" thus making the project week also a competition between the teams.

Extension to an interdisciplinary course embedded in the project KIVA
From 2011 till 2016, TU Darmstadt has been funded for the project "Development of competencies through interdisciplinary integration from the very beginning" (German acronym KIVA). It is a university-wide project funded within the German national program "Quality Pact of Teaching" ("Qualitätspakt Lehre") by the German Ministry of Education and Research (German acronym BMBF). The sub-project KIVA V has the purpose to transform the existing disciplinary project courses into interdisciplinary project courses as well as establish new ones. The vast majority of these projects are implemented with the underlying didactic concept of IGE as described in this paper, but there are project specific adaptations regarding disciplines' specific culture. All these design project courses are well evaluated. Thus, quantitative and qualitative data are being collected within an overall evaluation framework and in close cooperation with the faculties and administrations. The evaluation is externally supervised and feedback is given on a regular basis in order to overcome identified limitations and to support success factors. It is being investigated how and to what extent KIVA provides resources such as new interdisciplinary teaching formats or project-based course support tools. Moreover, the evaluation looks at processes such as course management or student advisory services and how KIVA influences them. Where possible and feasible, we measure the impact KIVA has on performance indicators like student evaluations of teaching directly after the course and also retrospectively years later. Last but not least, we obtain student self-reports about acquired competencies in all courses. Within the boundaries of protecting data and confidence, we also gather aggregated data about teaching induced knowledge, skills, and abilities as perceived by teachers and examiners. Currently, it is being investigated how, for example, psychology students benefit from KIVA[23].

IGE-GER was originally developed as a project week for Mechanical and Process Engineering but over the years it has expanded to be interdisciplinary with projects with the Biology, Political Science, Philosophy, Chemistry, and Economic Engineering Departments. Though the interdisciplinary course, students must learn to work with, communicate with, and integrate views from students from other disciplines for a successful project. This adds another challenging aspect to the course but new learning goals as well. The students have to realize the impact of different fields on each other, for example, the impact and interrelatedness of technology and its development as well as societal and human welfare. It has been observed by the authors that participants in the interdisciplinary projects have behaved as self-confident representatives of their respective fields. Examples of previous design tasks include “design of an autonomous robot to collect and separate trash at festivals,” “design of a kinetic recovery system integrated into a bicycle only using basic principles,” and “design of platform for plant seeds to reverse desertification over a large area including a mineral and water source for the plants.”

IGE as international summer school (IGE-USA)

In the summer of 2012, IGE-GER was expanded as an international course offered during the summer semester at TU Darmstadt (we will refer to this course as IGE-USA for simplicity). This course is also interdisciplinary with students from mechanical and process engineering, chemical engineering, and materials science engineering from two American universities, South Dakota School of Mines and Technology and Virginia Tech, and mechanical and process engineering, business engineering, and economic engineering from TU Darmstadt. Students are in groups of 10-12 with a mixture of American and German students and the many disciplines participating. In the past three years, student teams have participated in design tasks such as “Design a process and product that makes use of the leftover forest biomass from logging operations,” “Design an energetically autonomous robot that reduces plastic debris in a marine environment to less than 1,000 particles per km^2,” and “Design a system that is capable of eliminating a quarter of the recently known objects of size larger than 30 mm of space debris in LEO (low earth orbit) within the next decade.” For a detailed description of the first year (2012), please refer to Hampe et al.[24].

IGE-USA is a scaled down version of IGE-GER. Whereas IGE-GER typically has approximately 650 participants, IGE-USA has between 20 and 40 participants. Because of the small size, more informal interactions are possible between the students and the support staff, e.g., technical and team advisors and professor(s). With the small size and increased interaction of the support staff and the student groups, the help desk is not employed for IGE-USA with the technical advisors and professors supplementing this role as needed. Another difference is the time line for the project week. As described above for IGE-GER, the students are broken into groups and introduced to the task on Monday morning followed by team building and group work on the task, but the entire task must be completed along with the presentation for their peers, professors, and judging panel by Friday evening whereas in IGE-GER the groups only need to be finished with their design task and have till the following Monday to complete their presentations of their final design product which are presented on Wednesday. With the shorter time frame, the scope of the design must be reduced along with any extraneous activities. Expert interviews during IGE-USA are scheduled Wednesday morning similar to IGE-GER since experience (through IGE-GER) has shown us that Tuesday afternoon is too soon with the groups being too early in the design process to formulate appropriate questions for the experts that will help their design solutions but Wednesday afternoon is too late with the deadline of late Friday afternoon to be completely finished.

After the project week, the American students participate in two weeks of industrial and cultural tours around Germany. These tours are intended to immerse the Americans in German social and industrial culture and give the students a glimpse into German industries and opportunities for students such as internships, co-ops, and study abroad experiences. After experiencing the methodology of German Engineering, they then obtain some insights of German Engineering in practice through these industry tours.

IGE in Mongolia (IGE-MNG)

This past year (September 2014), IGE-GER was extended once more to a new university in Mongolia, German-Mongolian Institute for Resources and Technology (GMIT) (this version of the course will be referred to as IGE-MNG). The students were in their first semester of engineering in mechanical, environmental, or mining engineering, but all students have the same curriculum for first two years, then specialize in their last two years. A task similar in scope to IGE-GER and IGE-USA was written but with relevance to Mongolian society. Their specific task was "Design a system that is capable of collecting and sorting litter along the roadside or on beaches, and that also might be used to sort waste materials at municipal landfills. The objects to capture and treat are sized between 10 to 300 mm. A robot should be able to clean an area of 1 km^2 per day in a plane landscape."

Due to the opening of the new university, GMIT, IGE-MNG was held over the course of a week and half instead of being completed within one week, Monday-Friday. The course was held over five full days and two half days beginning on a Tuesday and ending the following week on Wednesday. This gave the teams there an extra day to finish their final design. Similar to IGE-USA, a help desk was not a part of the support system since there were only two teams (23 students in total participated). IGE-MNG also did not have an explicit time for expert interviews, but the two groups were able to meet and discuss their solutions and problems with the professor as needed. Another major difference between IGE-MNG and IGE-GER and IGE-USA is the level of interaction of the technical advisor. With the principle of minimum help guiding the interactions in IGE-GER and IGE-USA, the technical advisor plays a more passive role unless asked specific questions by students and providing more general strategic advice and motivation than subject-intensive advice. In IGE-MNG, the technical advisor needed to take a more active role in subject assisted learning, the design approach, and in general motivation. One of the major challenges in teaching this course was the language barrier. The final presentations and reports did not fully address the progress and their solutions of the design task as was shown during their actual work.

Conclusions and future of IGE

Introduction to German Engineering has been a success in the Mechanical and Process Engineering Department at TU Darmstadt for over 15 years. Currently, it is reported that the overall dropout rate across Germany for university Bachelor programs is 33% but is higher for mathematics and natural science (39%) and engineering (36%)[25]. In the Mechanical and Process Engineering Department at TU Darmstadt, the dropout rate is currently approximately 20% with an overall trend of decreasing rates since the 2005/2006 student cohort. Although we cannot say to what degree the impact of IGE is, it is definitely positively affecting students. This approach not only introduces students to the German engineering design process but also improves personal and team competencies as well as working techniques. From this success, it has been extended as an international interdisciplinary summer course, IGE-USA, then brought to Mongolia and taught at GMIT, IGE-MNG. Our experiences have shown that IGE in all of its adaptions and forms have positive effects. A validation on the base of summative and formative evaluation data is in preparation.

Due to the continued success of IGE over the years, the course, in all three variations, will continually be further developed and improved to increase student competencies and success as working professionals in their respective fields. The original IGE-GER course at TU Darmstadt is being studied as a model for project weeks in other disciplines. Currently, nearly all disciplines at TU Darmstadt participate in project courses that are funded and supported by KIVA V and are implemented either as voluntary or mandatory depending on the requirements of the respective departments. The next step is to reach all first year students and require participation in interdisciplinary project courses.

Due to the large size of the project courses, the resources needed (man hours and financial) is large and the question remains how to minimize the costs (especially for the support system) without decreasing the gain of the students and is being studied by one of the authors. The international, interdisciplinary IGE-USA is currently in the process of expanding to include more universities and disciplines. The IGE-MNG course is being further adapted to build a better support system at GMIT, such as training upperclassmen that participated in their first semester to hold a help desk positions as another resource for the design, especially as the number of enrolled students increases. There are further challenges such as the language barrier and infrastructure/organization of the project course at GMIT that will need to be addressed in next years as the course expands there.

We are experiencing national and international interest in this type of project course especially in development and implementation of them and how to increase motivation and engagement of students through these project weeks[26]. This IGE concept is flexible and adaptable in the sense that it is independent from year of study and discipline and can be adapted for different learning goals and objectives such as focusing more team support or subject/technical support as needed. In 2013, one of the authors, Professor Dr.-Ing Manfred Hampe, was awarded the “Ars Legendi Prize” in Germany, which is Germany’s highest prize for teaching in higher education, most especially for his engagement in developing and supporting innovative learning concepts for engineering students and interdisciplinary project courses across TU Darmstadt in the context of KIVA V.

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References

1. Robinson MA; Sparrow PR; Clegg C; Birdi K (2005). Design Engineering Competencies: Future Requirements and Predicted Changes in the Forthcoming Decade. *Design Studies*, 25: 123-153.
2. Turley RT; Bieman JM (1995). Competencies of Exceptional and Non-Exceptional Software engineers. *Journal of Systems and Software*, 28(1):19-38.
3. Peschges K-J; Reindel E (1998). Project-Oriented Engineering Education to Improve Key Competencies. *Global Journal of Engineering Education*, 2(2):181-186.
4. Degraff E; Kolmos A (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, 19(5):657-662.
5. Mills JE; Treagust DF (2003). Engineering Education-Is Problem-Based or Project-Based Learning the Answer. *Australasian Journal of Engineering Education*, online publication, http://www.aaee.com.au/journal/2003/mills_treagust03.pdf.
6. Hoit M; Ohland M (1998). The Impact of a Discipline-Based Introduction to Engineering Course on Improving Retention. *Journal of Engineering Education*, 87(1):79-85.
7. Knight DW; Carlson LE; Sullivan JF (2003). Staying in Engineering: Impact of a Hands-On, Team-Based, First-Year Projects Course on Student Retention. *Proceedings of the 2003 ASEE Annual Conference & Exposition*.
8. Knight DW; Carlson LE; Sullivan JE (2007). Improving Engineering Student Retention through Hands-on, Team Based, First-Year Design Projects. *31st International Conference on Research in Engineering Education*, Honolulu, HI.
9. Marra RM; Palmer B; Litzinger TA (2000). The Effects of a First-Year Engineering Design Course on Student Intellectual Development as Measured by the Perry Scheme. *Journal of Engineering Education*, 89(1): 39-45.
10. Mahendran M (1995). Project-Based Civil Engineering Courses. *Journal of Engineering Education*, 84(1): 75-79.
11. Hampe MJ (2001). Einführung in den Maschinenbau – Ein Projektkurs für Erstsemester. Görts W (Hrsg.)*: Projektveranstaltungen im Studium an der Technischen Universität Darmstadt*. Bestandsaufnahme 2001. Darmstadt: Technische Universität Darmstadt.
12. Wolf S; Hampe MJ (2006). How to Provide First-Year Students with a Really Good Start to their Study Program. An Innovative and Effective Approach to the Course which includes both Active and Collaborative Learning Techniques. *Proceedings of the 113th ASEE Annual Conference & Exposition*, Chicago, IL.
13. Wankat P; Oreovics F (2005). Starting with Square One. *Prism Journal*, 11:46.
14. Seymour E; Hewitt N (1997). Talking about Leaving: Why Undergraduates Leave the Science. *Westview Press*, Boulder CO.
15. The Association of German Engineers (VDI-Standard). VDI 2223 Systematic Embodiment Design of Technical Products, Beuth Verlag.
16. Pahl G; Beitz W; Feldhusen J; Grote K-H (Hrsg.) (2013). Konstruktionsmethodik. Methoden und Anwendung erfolgreicher Produktentwicklung. Berlin: Springer.
17. Görts W (Hrsg.) (2001). Projektveranstaltungen im Studium an der TU Darmstadt. Bestandsaufnahme 2001. Darmstadt: TU Darmstadt. [Schriftenreihe Wissenschaft und Technik, Bd. 82]
18. Möller-Holtkamp S (2007). Fachintegrierte Förderung von Teamkompetenz. Berlin: Logos.
19. Görts W (2009). Projektveranstaltungen und wie man sie richtig macht. Bielefeld: UVW.
20. Downey GL; Lucena JC; Moskal BM; Parkhurst R; Bigley T; Hays C; Jesiek BK; Kelly L; Miller J; Ruff S (2006). The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently. Journal of Engineering Education, 95(2):107-122.
21. Eger M (2011). Auf dem Weg: Studienreformprozesse am Beispiel der Kompetenzentwicklung durch Studienprojekte. In: Eger M; Gondani B; Kröger R (Hrsg.). *Verantwortungsvolle Hochschuldidaktik: Gesellschaftliche Herausforderungen, Nachhaltigkeitsanspruch und universitärer Alltag*.Berlin: Lit.

22. Zech F (1977*)*. Grundkurs Mathematikdidaktik: Theoretische und praktische Anleitungen für das Lehren und Lernen im Fach Mathematik. Weinheim: Beltz.
23. Koch FD; Vogt J (manuscript submitted). Psychology students in Darmstadt benefit from a large-scale project to improve university teaching. *Psychology Learning and Teaching*.
24. Hampe MJ; Bohn JH; Dixon, DJ (2013). Introduction to German Engineering. A Transatlantic Experience. *Proceedings of the 120th ASEE Annual Conference & Exposition*, Atlanta, GA.
25. Schmidt M (12.23.2015). Lasst sie nicht fallen. In DIE ZEIT. *Chancen*, No. 53, p.67.
26. Hampe MJ; Dirsch-Weigand A; Koch FD; Awolin M (accepted): Motivating First Year University Students by Interdisciplinary Study Projects. *Lilly International Spring Conference* (May 28-31, 2015). Bethesda, Maryland, USA.