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An Experiment in Design Pedagogy Transfer Across Cultures and Disciplines*

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The pedagogy of project-based courses is notoriously difficult to transfer but in today's global economy it is crucial to be able to teach innovation. Therefore, an experiment was performed to evaluate how a design innovation course could be transferred across cultures, disciplines and institutions. Specifically, a graduate level engineering design course from Stanford University was emulated at the University of St Gallen in Switzerland. The course methodology exemplifies the innovation approach taken by notable companies that represent the innovation success of Silicon Valley. The results obtained from a series of interviews indicate that there is a set of essentials to this pedagogy, which, when transferred, led to similar innovation success elsewhere.

Keywords: Project-based learning; design education; design thinking; pedagogy; innovation; education; failure; iteration; motivation; team formation; coaching; transferability autonomous learning

WHY SHOULD WE TEACH DESIGN INNOVATION?

THOMAS FRIEDMAN [1] writes in his book on the globalized or 'flattened world' that a Western company can hire five Chinese researches with Ph.D. degrees for the price of one researcher from a developed country. The continuing fall of trade barriers and drastic reduction in communication costs mean increased competition from developing countries for knowledge-based jobs. According to Friedman, the only way for developed countries to keep up with the competition from emerging economies is through a change in work morale and an improved ability and willingness to innovate and take risks. Silicon Valley, which is famous for its entrepreneurial spirit and the innovations created in the area, may constitute a model for this change. Companies such as Apple, Cisco and Google were all founded almost accidentally by entrepreneurs who had an idea and 'just tried' it commercially [2, 3, 4]. This 'just do it and do not be afraid of failure' mentality is at the basis of much of the economic value created through innovation in Silicon Valley, which remains unparalleled even after the dot-com bust. Ten percent of all inventions filed in 2003 with the US Patent Office originated in Silicon Valley [5], though it comprises far less than ten percent of the population and area of the US. At the core of this success is an innovation method called Design Thinking.

Design Thinking originated in engineering with the notion that analytical knowledge of technical systems is not sufficient to understanding and emulating the thought processes that lead to successful synthesis or design [6]. Although 'even "design" faculty—those often segregated from "analysis" faculty . . . have trouble articulating this elusive creature called design' [7] the characterization of engineering work as '[to] scope, generate, evaluate, and realize ideas' [8] helps define the term. However, this definition does not only describe the work of engineers but that of everyone creating something new. Dym *et al.* [9] write: 'design problems reflect the fact that the designer has a client (or customer) who, in turn, has in mind a set of users (or customers) for whose benefit the design artifact [process or service] is being developed'. Based on this understanding of design and the corresponding problems in design, Design Thinking can also be applied in fields outside engineering to help create innovation. A good businessperson, for example, does not only apply analytical skills to read financial reports, but must attend to the client or customer wishes as well.

The design consultancy IDEO, one of the top ranking innovative companies in the world, has demonstrated for many years the interdisciplinary application of design thinking to innovate successfully. If we are able to teach students the methodology, which IDEO uses, we have a chance to preserve our standard of living through increasing work morale, taking more risks and creating more innovations as postulated by Friedman. Since IDEO is a spin-off of Stanford University (SU) and maintains close ties to the university, we focus on design thinking at SU. We examine the methodology employed in the design group at SU to learn how design innovation can be taught, and to determine whether it can be taught effectively at other universities.

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The overarching goal of this study is to further an understanding of the factors that comprise SU's design innovation pedagogy, and to determine if and how educational institutions in other environments and cultures can successfully adopt the methodology. In order to achieve this goal, a pilot case study was performed, where SU's flagship project-based design innovation course, Engineering 310 (310), was transferred to the information technology management program at the University of St. Gallen (HSG) in Switzerland.

HOW CAN WE TEACH DESIGN INNOVATION?

How is design innovation taught at Stanford University?

SU's design innovation course, 310, is a graduate level engineering design course, in which about 35 students participate in corporate-sponsored real-world design projects. Student teams produce 7-10 innovations, with an average of two patents, each year. The course uses a project-based approach, which is based on the finding that that project-based learning enhances the student's motivation and retention [10], makes them better communicators and team members, and facilitates life-long learning [11, 12, 13].

Course and Team Structure: Primary emphasis is placed on composing balanced teams rather than matching students to first-choice projects. This is supported by research: Wilde has applied Jungian typology and the Myers-Briggs Temperament Indicator (MBTI) to the formation of student project teams in engineering and other disciplines. His research has shown that the likelihood of a successful outcome is increased by forming teams consisting of members with complementary roles, a plurality of viewpoints, a neutral manager and a 'wild card' [14]. In addition, Carillo studied the effect of six diversity factors—gender, ethnicity, years of experience, technical discipline, MBTI, and distance from campus—and even though he could not tease out any individual factor statistically, the results support the case for maximizing diversity [15]. Therefore, the 310 teams are formed first, approved by the teaching staff, and only then pick their favourites among the available projects as a team. This process is different from most other environments where usually teams are formed semi-randomly as members pick or are assigned to a project individually, with no consideration for the team composition.

The student teams tackle the corporate problems over the course of seven months, and develop a fully functional product prototype of their solutions. Several milestones, intermediate prototype reviews, and presentations to the company (Fig. 1) help structure the project and ensure that results remain with the company's expectations.

Workspace—The 310 Loft: The course has its own designated workspace, called the Loft, which resembles more a design studio space than a classroom. In this room, each team has its own 'private' area, which it can decorate and personalize. The Loft also houses a variety of basic hand tools and building materials for prototype construction, and the necessary infrastructure to adequately support the project work. This includes computer terminals with CAD and video editing stations, printers, phones, fax machines and video conferencing equipment. The availability of basic tools and building materials in thinking spaces is uncommon in both the business and academic world, where design creation and prototype fabrication are usually separated by organization of space and personnel. The intermingling of designing and fabricating in the 310 process and workspace encourages the frequent construction of simple prototypes, which greatly increases the potential for 'accidental discovery', while shortening iteration cycle times and reducing the risk of designing based on false assumptions.

People and Interaction—The interaction between all parties involved in 310 is a core component of the course and the design thinking methodology. This interaction can be separated into six distinct channels as follows:

1) Intra-team: The students in a particular team interact through meetings in the Loft, email, instant messaging, and phone. The large number of channels here enables the teams to interact at any time and from virtually anywhere.
2) Team/Instructors: The teaching team (two full professors, one consulting professor/technical specialist, and three teaching assistants) meets weekly with each student team to discuss project progress and future steps. These small group meetings (SGM's), last for about one hour and are characterized by a high level of interaction and open exchange of ideas, suggestions and critique from a multitude of viewpoints, as well as referrals to experts from outside the 310 community for help on particular problems. The multitude of views considered throughout the course of the project is an integral part of the design thinking philosophy and is different from most projects, where the goal is to reach agreement and closure as early as possible.
3) Team/Coach: Every team also receives support and guidance from a coach who has professional experience in the area of the project. The coach's role is to advise the students based on their technical expertise, and to help with project and team management. Studies at a major automotive manufacturer have shown that such a "process expert" who is assigned to coach, rather than direct or manage, a design team creates a third learning loop [16] and thus functions as a knowledge broker in ways similar to the organizations described by Hargadon [17]. The coaches, who often join for the SGMs, also meet separately with the student teams once per week.

4) Team/Liaison: The project-based nature of the course also requires the student teams to interact with their liaisons from the companies sponsoring their projects. The liaisons meet with the students through regularly scheduled meetings or conference calls, but they are not included in the intra team communication, so as to preserve a sense of professional distance as appropriate for the desirable customer-supplier relationship described by Dym *et al.* [1].
5) Inter-team: Interaction between the various student teams is also important to facilitate peer learning, to utilize student know-how, to provide motivation through competition. Therefore, private team spaces are open to enable and encourage awareness of work and progress by other teams. In addition, each student is required to attend at least two other teams' review meetings at each milestone. By observing the problems, successes, and methods of the other teams, each student learns from multiple projects rather than just his or her own.
6) Full community: The various modes of interaction described before, all come together at the weekly Slightly Unorganized Design Session (SUDS), an evening get-together of everyone involved in 310, over food and drinks. Each week, a different student team takes responsibility for organizing and providing food of their choice for the entire class in the loft. This unique social design activity, allows students, instructors, coaches, liaisons and alumni to interact casually, talk about their projects, other classes and life in general, which helps create an atmosphere of friendship and trust in the 310 community.

What are the essential elements of the pedagogy, which must be transferred?

The above description of 310 at SU is the basis for the following recount of how the course was transferred to HSG. In order to test the transferability and effect of SU's design innovation pedagogy in another environment, culture and discipline, the course at HSG was modelled closely after the original at SU. 310 at SU, however, has developed through decades of implementation, and many aspects of the pedagogy remain unacknowledged even by insiders. This section therefore describes which aspects of 310 were considered essential to the pedagogy and transferred, and how the resulting course differed from the original. Based on the experience in 310 at SU, the following factors where considered vital components of the design methodology, indispensable to the successful transfer of the innovation pedagogy in design:

1) Space and Infrastructure: A designated space with an ambience that stimulates creativity and provides the infrastructure necessary for project work.
2) Development Structure: A multitude of deadlines for assignments, which are open-ended with respect to content, but specific with respect to process, to drive the project forward and to provide starting points for the students.
3) Regular Meetings with Reviewers: Weekly

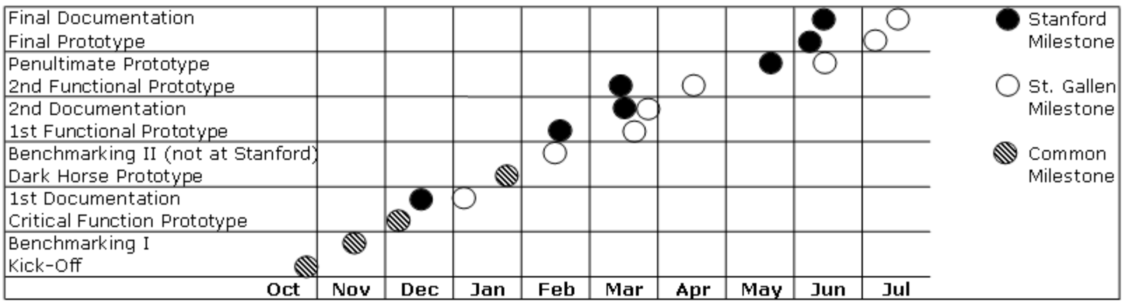

Fig. 1. Comparison between the assignment structure and schedule at SU and HSG

Table 1. Comparison between attributes of 310 at SU and at HSG

Attribute	Stanford University (SU)	University of St. Gallen (HSG)
Academic discipline	Mechanical Eng.	Information, Media & Technology Mgt.
Class size (students)	36–40	6–7
Number of student teams	10	2
Number of corporate partners & projects	10	1
Number of teaching team members	6	1–2 at a time
Credits received for class as percentage of full time student status	40–50%	10%
Duration of corporate project (in months/included vacation time in weeks)	7/4	8/13
Average number of nationalities on a team	ca. 2.8	1.5
Percentage of teams with coaches	100%	50%
Warm-up exercise to course	Yes, 6 weeks	Negligible, 45 minutes

meetings between the student team and teaching team to ensure continuous progress, to provide a variety of inputs and to provide an early warning system for potential troubles.

4) Diverse Team Composition: Student teams of no more than four members, to enable efficient interaction, and diversity in background, experience, and personality to increase the number of input factors within the team.
5) Multiple Teams and Peer Reviews: A minimum of two student teams that work side-by-side, to create a sense of competition between the teams and to enable the students to learn from two project experiences rather than only one.
6) Social Interaction: The relationship within the student teams and between the students and instructors must be extended from the professional to the personal level, to create the trust that enables the discussion of failures and wild ideas.
7) Coaching: The advice of a coach who does not measure the students, but facilitates learning by providing an outside perspective, thus becoming the trusted third party if problems with the teaching team arise.

The above factors were all implemented in the transfer of the course to HSG. Given the different circumstances at HSG, however, other factors were left (intentionally) different, as summarized in the table below or explained in detail afterwards.

Unlike the teams at SU, at HSG, the two students teams shared their workspace. However, the students at HSG were also asked to decorate their room and they named it 'La Boheme'. This room became the centre of the project and provided the students a home on campus, which they could also use for other work (as at SU), allowing them to easily start and end their project work anytime without needing to move notes, mock-ups, and other work around. La Boheme also housed the infrastructure for the course. This included a printer, video camera, projector, large whiteboard spaces and a computer terminal, with the walk-up collaboration software TeamSpot by Tidebreak. (No prototyping tools or materials other than some Legos® were provided, since the course was geared towards the development of a software interface instead of mechanical hardware). Even though La Boheme was not as large as the 310 loft at Stanford University and was not used 24/7, the students did use it regularly for project and other work or simply to relax between classes.

The course and assignment structure was taken directly from SU. In order to orient the requirements towards software developments the wording of assignments was modified. The grading weights were also adjusted for the change from a three quarter course to a two-semester course. Similarly, the order and timeline was modified slightly based on the differences in academic calendars.

Similar changes were made to the introductory lectures, which were condensed from seven ninety-minute lectures by two professors to two two-hour sessions, one of which included a small design exercise. Those sessions used materials from 310 at SU.

At HSG, the two student teams were formed according to similar rules regarding diversity, as at SU. Since there were only seven students in the course, we were unable to achieve the same level of team diversity as at SU. Still, the MBTI method [14] was used and the two teams were formed to maximize gender and personality diversity.

Each of these two student teams met weekly for about one hour with the HSG teaching team to discuss the progress and future steps, as at SU. The teaching team at HSG, however, was much smaller and thus the students usually received only one opinion on any question, while at SU, the teaching team usually has a variety of viewpoints, which forces the students to pick the best among multiple suggestions. This lack of diversity of opinions made these SGMs at HSG less chaotic but potentially also less creative, as pointed out by students who wished that they had received a greater range of opinions.

In addition to these SGMs, the entire class, students and teaching team, held SUDS once per week in the cafeteria. The two student teams alternated on the responsibility for organizing food and drinks.

One of the two student teams also interacted with a coach, a former manager, who joined most SGMs and an additional team meeting every other week. Since he was not a professional expert on the details of the project, his role was to coach the team on team interaction, presentation and organizational skills, to provide the students with an outside perspective and to act as a moderator during conflicts, if necessary.

What did we learn about transferring design pedagogy?

The results of the course satisfied all goals of teaching design innovation in a project-based course: student learning, innovation creation and partner company satisfaction. In interviews, all students clearly explained that the methodology was the cause for their innovation success, and motivated them to spend approximately 25 hours every week on a project, which accounted for only 10% of the credits awarded in each of the two semesters of the course. Similarly, the corporate partner's satisfaction with the results is evidenced by the fact that SAP, the enterprise software company that sponsored the project, more than doubled its financial contribution to the course during the following year based on the outcome of this course. This is further emphasized by the following quote:

> [This was] a great experience for all involved parties, and the first step to a very innovative task management killer app[lication]! The motivation of the students was immense and the results were well beyond expectations! Markus D. Schneider, SAP AG

Additionally, Prof. Larry Leifer, Ph.D., one of the 310 co-developers, stated that he found the results developed at HSG comparable to the work created at SU. These results clearly demonstrate that SU's design innovation pedagogy and its success effect are transferable to other disciplines, cultures and environments.

DATA GATHERING—STRUCTURED INTERVIEWS

The nature of the underlying question, 'What makes this design methodology work, and how can it be transferred to other environments and cultures?' requires us to address 'a symmetrical, coherent and well-balanced whole, a gestalt' [18] during phase-1 of this multi-stage research study. An open-ended qualitative data collection method, such as semi-structured interviews, is appropriate for achieving this goal, whereas a numerical analysis would be premature at the current stage of the research. Thus, forty-five minute interviews were held with each student individually after completion of the project. The students were first asked what they consider to be the reasons for their innovation success, and then to what extend which factor of the design methodology impacted their work methods and results. In some cases one or more of the following topics were mentioned to stimulate the conversation: room, team composition and MBTI, SUDS, relationship within team and with teaching team, class and assignment structure, iterations and coaching. In addition, towards the end of each interview, they were asked what they would do as managers, when asked to create a totally new product or service for their employer. The results of these interviews are complemented by observations made by the first author, Skogstad, who has experienced 310 at SU as a student and member of the teaching team and led the teaching team during the offering of the course at HSG, where he was in contact with the students at least twice per week for the eight months of the project.

RESULTS

On the whole, the interviews and observations supported our preconceptions regarding key factors. However, during the analysis, we also discovered two additional factors that appear to have been important to the HSG instantiation of the 310 pedagogy. These are the importance of 1) a sense of responsibility on the part of students beyond grades and 2) the quality of relationships within the community, which results in an inspiring atmosphere.

Space and Infrastructure: all students mentioned that the room, which was solely used by the course, not only differentiated this course more from all other courses but also affected their work physically and cognitively. The room allowed them to easily stop and resume their work at anytime without the usual loss in setup time, and more importantly it was an environment that facilitated open exchange. The students said that the ambience of the room not only created an atmosphere of privacy and comfort that allowed them to speak openly, but also enabled them to think openly and thus be more creative. They argued that the decoration, couch and music indirectly created flexibility in their thinking because it made them more relaxed.

One student made the comment that 'a crazy environment leads to crazy ideas'.

The importance of this atmosphere is also described by Barker [19], who interviewed a prolific researcher at Bell Laboratories. He states that the 'best ideas seem to have popped up when he was [. . .] in relaxed settings' and it was 'sort of like a jam session. We were having fun'. The room for the course helped create the necessary ambience to allow for this kind of interaction. Another student said that the large drawing space on the whiteboards allowed him to think more openly. His experience was: 'If I work with an A4 [~US Letter] piece of paper, I will think in A4 while if I work on an entire wall, my thinking can go far outside the box'.

Despite popular opinion, capital investments into building infrastructure are not necessary to support creative work—in the case of this course, a standard university office was easily converted into a design studio by mounting large whiteboards and bringing in 'stuff' like gift wrapping paper to cover the walls, Legos®, a CD-Player, and an old couch.

Development structure: Another key factor for the innovativeness of the students was the large number of iterations they produced. The majority of students explained that in every other class, they get one shot at a problem while in this course, they went through many test, refine and restart cycles, each time from a new angle. These iteration cycles not only resulted in a much more refined product, but they also allowed the students to make mistakes. They said that this encouraged them to try new and unproven ways because they knew they would have another chance to make it right. One student summed this up by saying that

'We had many ideas and with the large number of iterations, we were able to test at least some of them while usually we can only use the one idea, which poses the least risk'.

Thus, it is important for instructors to credit not only successes but also well-intentioned attempts that result in failure. Students can learn much more effectively if they are not penalized for failure, but instead are given the chance to improve through iteration, based on the learnings that emerge from their failures.

Multiple teams and peer reviews—'Coopetition': All students agreed that the effect of having two teams work side by side was an important motivator. The two teams were driving each other in a competitive way to better and better ideas because neither team wanted to fall behind. One student said that after a review session of the other team, his team gathered and felt 'Shit, were they good. We got to keep up with that'.

This form of motivation is commonly described as 'tournament theory', which must be carefully managed to avoid contests that label everyone a loser except the winner and thus dangerously reduce overall motivation [20]. Another student clearly alluded to this by criticizing the grading component of the peer review process. He said that when they had to assign a grade to the other team, it put both teams in a peculiar situation where they felt torn between honesty and friendship, which resulted in a negative attitude towards these reviews.

Comparing the process to SU, however, the student thought it was a good and productive process if more teams were involved, eliminating the 'us-against-them feeling' through diversification.

Similarly, if the teams were working on different projects for different corporate partners, the results would no longer be directly comparable and thus more cooperation would be encouraged. Despite this critique of the peer review process, the desired balance between competition and cooperation was accomplished since the student who criticized the peer reviews called the relationship with the other team 'coopetition' to describe the combination of competition and cooperation. All students said that they never held back any information from the other team and were always happy to help each other, which usually had a positive impact for both teams. Two students even described the other team as a safety net.

They felt that 'if we cannot save the project, at least they have something', which took some of the pressure of the responsibility off them.

Despite this differing viewpoint, all students agreed that the effect of working close to the other team and seeing someone else go through the same pains and joys was instrumental to their success.

Diverse team composition

All students declared during the interviews that the team composition, a topic, which is commonly ignored, was key and that each could not imagine being on the other team. This raises an important point: Initially, the students were assigned to teams seemingly without their own input just like they would have been anywhere else; however, they had indirect input through the MBTI test which they had taken at the start of the course.

One student said that the personality-based team composition method can be used as 'a perfect excuse for reshuffling teams', which he thought was important because he found that 'the same people will always have the same ideas and therefore to create something new, one must create new teams'.

The same student also stated, 'this [MBTI-based] method ensures that the wrong people are not put on the same team'.

The other five interviewees described it as a key to building teams with good relationships and stated that they would like to use this method in future work situations. Four of the six interviewees specifically alluded to the fact that the unusual situation with no designated leader gave everyone equal power in discussions and helped designate each task to whoever was best suited for it.

One student compared this to the dynamic change in leadership at the front of a bird swarm. He said that 'whoever was best suited for the task at hand and available would do the job, and then someone else would take over for the next part while the first could then move at a slower pace'.

This statement correlates with the motivation created within the teams. All students but one specifically said that they did not want to disappoint their teammates and therefore worked at least as hard as the rest of the team, thus creating an upward spiral.

Social interaction: (SUDS): SUDS was described by all students but one as instrumental to the course and a cornerstone for its success. This weekly event not only helped the development of the relationships between people but also made the students feel part of a special task force, setting a standard, which they would have to live up to (thanks to SUDS, the course was known across campus as the 'Rotweingruppe' [red wine group]). The students also suggested that SUDS made the course a more rewarding experience and helped it traverse all aspects of their lives. One student commented that 'Initially I felt that SUDS was just sucking up more my time, but I quickly learned that this was an evening spent among good friends'.

All of them including the more SUDS-critical student described this weekly event as particularly important for the relationship with the teaching team. They explained that

the casual talks with the teaching team at this event gave the message 'we are always there for you' and created 'the openness and trust that allowed [us] to ask dumb questions'.

Furthermore, they contrasted the relationship between students and instructors with other courses by emphasizing the respect both parties were paid. This different attitude is best illustrated by the second instructor's late entry into the project at the half-time point. Since the students were deep into their projects and the instructor was unfamiliar with the project, the students were very sceptical of her at first and considered discussions with her a waste of their project time. However, this instructor quickly adapted to the culture of the course and 'earned the student's respect through her positive and helpful work'. The effect of this was that

the students were 'not looking up to her anymore because she is an instructor but that both sides were on the same level and therefore we were able to talk to each other more openly BUT WITH RESPECT [emphasis included]'.

Regular meetings with teaching team and coaching: The experience at SU suggested that it is important to separate the teaching or measuring function from the outside coaching or mentoring function. Interestingly, however, the study at HSG suggests that the students' perception of the instructor's role as a coach versus an instructor is actually paramount. At HSG, only one of the two teams was supported by a professional coach external to the teaching team. Even though all members of this team described the influence of this coach as extremely helpful to their own professional development because he acted as a mentor, they also agreed that the coach's input to their project work was limited. Both teams, however, noted that they perceived the teaching team not as a boss, but as a coaching body. They argued that the trusting relationship was important for creating an environment where the exchange of knowledge, experience and opinion is encouraged. One student formulated this as:

"the teaching team was acting as an alarm system and coach, and not as a boss or professor". He continued by saying that 'one tries to satisfy the expectation of a boss or professor as [well] as possible, while one wants to make a coach proud, which is much harder'.

This finding suggests that instructors should place more emphasis on building a rich relationship with the students rather than relying on outside coaches to do so.

Motivation and attitude through responsibility and high expectations

All six students pointed out the differences in motivation in this course versus their other courses. They all agreed that in this course their motivation was based not on their grades, but on their responsibility.

The students argued that this responsibility was due to the special situation that a company had effectively paid them, and that they were responsible for HSG's and the institute's reputation. One student said, 'This was the first time WE [emphasis included] had responsibility for a result and [for] the university'.

The other students described their motivation in similar ways and they all agreed that, thanks to this responsibility, they were no longer concerned about the hours put in this course but simply about the quality of the result. Even though this kind of responsibility and the resulting motivation is common in business, it has only recently entered education with the advent of project-based courses [1].

All students mentioned that 'we were intrinsically motivated because we identified directly with the project results', and thus they 'saw the project as a baby'. The students further argued that in this course, they 'felt taken seriously for the first time' and were 'in the driver's seat making the decisions' because they were encouraged to pursue their own ideas and to bring in themselves.

One student described their sense of self-actualization starkly by saying that 'unlike in frontal lectures where junk is poured over us, we can bring in our expertise and experience'.

The respect paid to the students by the teaching team and the responsibility for the university's reputation also boosted the expectations on all sides. All students mentioned that this course was not about efficiency but about satisfying SAP's, the teaching team's, and their own expectations.

One student commented 'In every other course, you work by the SABTA [Selbstsicheres Auftreten bei totaler Ahnungslosigkeit / self-confident appearance with total ignorance] principle and are only concerned with what is the best possible grade for the lowest amount of work'.

He argued that in this course, this approach did not work for two reasons: First, the teaching team clearly communicated that anything not new or innovative would not be acceptable, and secondly that the requirement for implementation with prototypes made it impossible to get away with great theoretical concepts that would not sustain reality.

WHAT SHOULD WE DO NEXT?

The study described in this report has shown that the design innovation pedagogy of SU is transferable and can boost innovation in other environments, disciplines and cultures as well. However, this study was based on a small data set with only two samples from the same environment. Therefore, the study must be viewed as a first indicator rather than scientific evidence for the conclusions made. Still, the study should constitute the basis for future research.

To date, the ability to innovate has been studied primarily at the organizational and individual levels, but only sparsely at the work team level [21]. Since most innovations, however, are created in small work teams, it is important to understand the dynamics and roots of innovation at this level. Based on the results of this first study, the following hypotheses can be made. These should be tested through future research and whenever possible, in controlled experiments.

Hypothesis 1

The absence of a designated team leader boosts the team's ability to innovate because more ideas will be floated and tested since there is no team leader who can abort an idea without evidence for its inaptness. Rationale: the design teams in this study did not have a designated leader, which was perceived as an advantage by all team members.

Hypothesis 2

The level and quality of the relationship between the members of a design team affects their ability to innovate. If the team members build a relationship of friendship and trust with each other, they are more likely to innovate because they will be open to articulate wilder ideas in discussions.

Hypothesis 3

The level and quality of the relationship between design team and superior affects the ability to innovate. Rationale: first, the design team will be more willing to share failures with a superior who can often provide help, and secondly because the design team is more motivated to satisfy the expectations of a coach who struggles together with them rather than acts as a distant boss.

Hypothesis 4

The playfulness and home-like atmosphere of a work environment has an indirect impact on the ability to innovate. Rationale: it provides more inputs and the relaxedness that allows the mind to 'un-focus' and thus reach into new idea spaces.

Hypothesis 5

The design thinking methodology helps overcome the resistance of individuals to teamwork. Rationale: team members depend on each other to achieve a shared goal.

The five hypotheses listed above are suggested by the findings in phase-1 of the 310 pedagogy transfer experiment. This study has answered its initial two questions while posing new ones, laying the basis for future research.

A second phase experiment in transferring design innovation pedagogy is currently (academic year 2007–2008) being performed at a large public research university on the US East Coast. Although this experiment has a different set of limiting factors, we see opportunity to study these hypotheses further, to expand the data set, and to test the transfer of key factors in another distinct academic institution and culture. Limiting factors include: different student population (undergraduates vs. graduates at SU and HSG), course length (16 weeks vs. 30 weeks at SU and HSG), and absence of a dedicated classroom space. The focus is in particular on hypotheses 2, 3 and 5, and we believe that thanks to creative planning we minimized the effects of some of the factor differences.

CONCLUSION

The motivation shown by the students, and their assessment of their learning success in this course make a strong point for project-based courses. In such courses, 'the information is not presented on a shiny platter' as one student put it, but instead the students are required to learn to find and filter information themselves. Because once the students graduate, there will be no instructor who has already found the few golden nuggets of information needed to complete a specific task, learning this process of realizing what needs to be learned is an important prerequisite for 'Lifelong Learning'—one of the recently phrased goals of education [1].

The fact that in this course, the students felt like they were given responsibility for the first time is best shown by the statement of a student who commented at the final presentation at SAP that 'I no longer felt like a student presenting student work but like a professional presenting and selling a great product'.

Similarly, in their evaluations of the course, the two most important questions 'How would you evaluate the course overall?' and 'How would you evaluate your learning success in this course?' were both answered with an average score of 1.2 out of 5 (1 being the best).

One student wrote in an evaluation 'This was the best course ever', and during a meeting with the university's administration, the three students present declared in unison 'we learned one half of everything we learned in the Masters in this course'.

The positive assessment of this project-based course from a pedagogical perspective is underlined by another student, who said 'after this course I feel as an adult', referring to the increased ability to tackle large projects.

It is important, however, to also understand the limitations of project-based courses. The students in this course had spent one half of their available time on one tenth of their credits. If every course wanted to accomplish this, the students would have to spend five times more time for their courses in total, which is simply impossible. Therefore, a clear differentiation must be made between project-based courses, which are oriented toward practical results, versus lecture courses, which are more efficient for learning large amounts of theory. It is possible, however, to combine the two, to some extent. A mechatronics course at SU does this as follows: throughout the semester, the students attend lectures and complete homework assignments, but instead of a final exam, the students build robots in teams and enter them into a competition. This way, the material is presented in an efficient fashion, but instead of memorizing material for an exam, students spend their time designing and building robots. This allows them to review all the material in a playful fashion, and to demonstrate their ability to apply it in practical problem.

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