Technology and Need as Starting Points for Innovation - Experiences from Multidisciplinary Student Teams

Ms. Tuuli Maria Utriainen, Aalto University

Tuuli Utriainen is keen to deeply understand the human experience. She's worked in the borderline of various fields and facilitated over 60 global teams engaged in human-centered product development. Tuuli is currently working at CERN, where together with her team she's established the IdeaSquare unit. Its purpose is to connect the technological know-how and radical thinking of CERN to solve some of the human kind's biggest issues.

Dr. Ville Taajamaa, University of Turku

Ville M. Taajamaa, D.Sc (Tech), research focus is in engineering education research, and new product development. The main outcome of his recent research is an action–based education framework and a new model for interdisciplinary engineering education: O-CDIO where emphasis is more in the first phases of the engineering process: Observe-CDIO compared to traditional engineering education focusing mainly on problem solving. The core idea is to educate engineers to become excellent problem definers in addition to becoming problem solvers. In practice O-CDIO combines natural sciences with human-centered sciences into a single education structure with embedded design thinking processes and methods.

Mr. Raghu Ram Movva, SAFM - College des Ingenieurs Italia

Academic background in Nanotechnology from multiple universities - EPFL (CH), INPG (FR), Politecnico di Torino (IT) & UC Berkeley (US). After a brief stint in strategic consulting, co-founded three start-ups - Smart-park, MTCS & Brava Italia. Later after obtaining, an MBA from Collège des Ingénieurs (CDI), currently heading the Innovation department in CDI ITalia which includes projects like Innovation for Change (Impact Innovation project - joint collaboration by CERN, Politecnico di Torino & CDI Italia), CDILabs (An open-innovation project that helps build sales relationships between MNCs and Startups) and School for Entrepreneurship. Passionate about technology, education, science fiction, applied futures and innovation.

Mr. Joona Kurikka, Aalto University

Joona Kurikka is a PhD Researcher at Aalto University and Associate at CERN, working at the innovation experiment IdeaSquare. As part of his work at CERN, he is coordinating and teaching student project like Challenge Based Innovation and various smaller innovation workshops, hackathons and other projects. His current research focus is on processes and ICT tools for distributed collaboration and learning.

Technology and need as starting points for innovation – experiences from multidisciplinary student teams

In research organizations, the starting point for innovation is typically technology developed in-house and the application of it in a novel field. The authors have experimented with an unconventional approach in the context of CERN, where course structures start with a need instead of technology.

We introduce an open-ended course Innovation for Change that utilizes design thinking as an underlying structure. The course sets considerable emphasis on the first phases of the design thinking process, which include ideation, observation, need finding, and early phase prototyping.

In order to understand the preferred starting points for innovation (need, technology or self-defined), the students' opinions were gathered through an online survey post kick off and post project. The data was analyzed with both statistical and qualitative methods.

The research results demonstrate that the students had a slight preference for need-based challenge framing in the start of the project. However, by the end of the project their preferences were fairly evenly divided between the need, technology or self-defined challenge approaches. Some evidence was gained to support the hypothesis, that the students would find a need-based challenge framing motivating. In future research different demographic groups could be surveyed to find differences in e.g. field based or cultural perceptions.

Introduction

The research in this paper was done in the context of a course called Innovation for Change (IfC) which hosts a variety of multicultural and multidisciplinary student teams that aim to solve both semi-structured and open-ended problems.

The course participants go through several cycles of design thinking process in order to achieve the mindset of a designer [1]. The learning approach follows the progressive school of thought and focuses on methods that are a mix of experiential learning and problem based learning [2,3,4,5]. This leads to a transform also at the mindset level, for example the tolerance towards ambiguity increases [1,6]. From the perspective of logical reasoning or epistemological worldview there is a clear emphasis on abductive and reflexive approach instead of deductive or even inductive reasoning [7]. University education and STEM (Science, Technology, Engineering and Mathematics) tends to focus on disciplinary problem solving with emphasis on deductive and rational processes [8,9]. Assessment methods and learning taxonomies are build on cognitive metrics that can be measured and the affective-emotional processes are left un-assessed [10]. This study does not try to solve the complex and interconnected system of cognitive-rational and affective-emotional learning. The aim is to shed light on the learning outcomes that are acknowledged by the literature to be of significance in terms of higher-order thinking and transversal skills. The same skills are widely seen as important in solving global grand challenges [10,11,12]. In this work the focus is placed on learning about alternative starting points for the design process from the students perspective.

Focusing on the need – design thinking

In this section we introduce the basics of design thinking as it is the underlying approach behind previously mentioned course in this article. Design thinking provides the needed process, methods and the general mindset used to observe and find the latent undiscovered user-centered needs. Design thinking acts as the ´glue´ also in latter phases of the product development cycles providing human-centered methods to otherwise technology driven projects.

In essence design thinking is used as a user-centred approach combining several different traditional disciplines. This is also one of the fundamental differences between technology-driven and need-driven innovation. Technology-driven innovations rely more on research on technology and problem solving based on natural sciences and engineering [13,14]. Design thinking does not exclude these, but aims to add on to the systemic thinking and to the research and technology-driven innovation approach by focusing on the user.

There is a vast literature on learning outcomes of Capstone courses and project courses in general [1,13,15]. However, educational innovations or innovations within education are a less researched area, for example what are the foundational skills and mindset that actually foster the capabilities needed in order to achieve innovations. Engineering knowledge and skills are important especially in technology-driven innovation, but our argument is that they are not enough. There needs to be a more human-centered and a transversal skillset added to that. In practice, skills such as communication, tolerance of ambiguity and teamwork can all be seen as qualities that are honed in course that focus on issues other than only engineering. Used wisely in an educational setting design thinking can facilitate these abovementioned skills. This particular area of research, which is stemming from educational setting has been less systematically researched. This surface boundary of education, especially engineering education, and innovation research is something that we hope to expand with this article. IfC utilizes design thinking both as a cognitive style as well as a general theory of design [16]. Typical course processes are team formation in a multicultural and interdisciplinary setting coupled with hands-on doing based on repetitive do-test-learn cycles that are constantly assessed and communicated by the teaching team.

Design, whether as design science or design thinking has been with us for quite some time. Already in the 1950´s B. Fuller, a renowned scientists and inventor described design science as: "…the effective application of the principles of science to the conscious design of our total environment in order to help make the Earth's finite resources meet the needs of all humanity without disrupting the ecological processes of the planet" Buckminister Fuller [17]. There is relevant criticism to be considered as well. The three perspectives, based on Kimbell 2011, are that when looking at design thinking are [16]:

1. There is a distinct dualism in design thinking between ´doing´ and ´thinking´. The cognitive school of thought
2. In reality there is diversity in how designers ´design´. All design and its practices are context driven and historically situated
3. In design thinking theories the designer is seen as the agent driving the process

As the project goals are linked with societal impact the fundamental course concept is close to the organizational design thinking paradigm defined by Brown, 2009 and Martin, 2009 [18,19]. These approaches defines design thinking as a vehicle for non-political and large-scale organizational change that shifts focus from looking for alternatives from existing options to creating new concepts [18,19]. The actual learning process follows more design thinking methods approach and "working in a designerly way" [18]. The technology brought in from the research organizations is often not plug-and-play but might need more fundamental shifts in ways of thinking about solving the issues at hand.

The purpose of the developed course is to explore the possibilities of bridging the gap between societal needs and advanced technologies. They also provide the participating MA and PhD level students with abilities to engage in large scale thinking while working on real world projects with tangible outcomes across disciplines. Many of the projects result in the students forming their own startups or continuing with the final gala after the class which seems to indicate that the structure is boosting the student's entrepreneurial skills and aspirations. This is linked with the heightened feeling of both self-efficacy and also reflexive engineer [20,21]. In this research we take a deeper look into what kind of preferences the students have regarding the starting points for innovation to reach an impactful outcome.

Innovation for Change

Innovation for Change (IfC) is a five month long impact innovation program that provides entrepreneurial education for interdisciplinary teams who tackle global challenges that are proposed by big industry/entities and use latest technology from research centres as an inspiration. The program is a collaboration between CERN who provides access to the technologies and Scuola di alta formazione al management (SAFM) and Politecnico di Torino who provide their respective expertise on business education and technology. The common goal is to create unconventional approaches for bringing technology in as an inspiration source for social impact projects, where the starting point for innovation is a pre-defined need.

The program ran first time in Spring 2016 with eight participating teams and its second iteration started in January 2017 with consecutive eight teams. The majority of students were MBA fellows from a highly competitive one-year program with varying engineering backgrounds who were mixed together with PhD and architect students. The latter were handpicked after a selection process for their strong technical backgrounds and entrepreneurial curiosity by their professors. The idea behind bringing in more experienced PhD students into the teams was to use them as a bridge between the sometimes difficult to understand technologies from the research institutes and the rest of the team.

The challenges are proposed by international entities that are looking to find innovative solutions to grand challenges within their industry/sector. These partner organizations bring problem related expertise to the student teams during the project by leveraging their sector expertise and existing networks. The challenges are formed together with the course instructors to be open ended, not to be organization specific and to have potential for large-scale positive impact. In the first edition, the teams sought solutions to following eight challenges linked with the overarching themes of Water and Air:

Team 1	Reducing Water Scarcity in Cities
Team 2	Providing Water for Industry
Team 3	Eliminating Water Leakages
Team 4	Providing Nitrogen into Soil
Team 5	Providing Water for Agriculture

Team 6	Improving Air Quality in Cities
Team 7	Reducing N20 Emissions
Team 8	Weather Forecasting for Energy production

IfC uses a need-based development approach arising from design thinking to create relevant products and services. The structure is based on work of professors from the partnering institutions building on the work of others on the field mentioned in previous chapters. Teams were given methodology inputs from the fields of need finding, prototyping, and business approach amongst others. The students were asked to consider three different timeframes regarding their solution: 20 weeks work plan, 20 months startup plan and a 20 years vision. One of the exercises to support their thinking was conducted in a session, where they were asked to create future utopias and dystopias to extract guidelines for the rest of the project.

The IfC projects started with a weeklong field trip to CERN to get an overview of the available technologies as an inspiration source for ideation. In addition, the teams had sessions with their assigned knowledge transfer mentors who would support the teams with feasibility questions along the five months. The teams also received their challenges from the problem framing organizations. The students then returned to Italy where they advanced their work during weekend sessions and evening hours throughout the Spring. The project came to an end in July in a gala in Turin, where the winning team was handed 50 000 euros to further develop their project.

Currently, four out of eight teams are continuing their projects. Team 3 has established a startup that is working with corporate partners to finalize their product development and have a pilot market study planned for Fall 2017. Team 4 is currently performing initial prototype testing with selected agricultural producers in the local area, whereas team 7's results have turned into an internal project inside its partner organization with a dedicated unit working on the foundation laid by the students. The world's first conference on N2O related climate change is being held this June by them. And finally, project results of team 8 are being used by their partnering organization as part of their corporate sustainability outreach program targeting high schools in central Italy. The rest of the teams are not continuing with the projects, according to the authors' best knowledge.

Need, technology or own idea as a base for innovation

Often entrepreneurship courses build on project ideas that are pitched by students. One of the IfC organizers was running projects previously starting from this point of view, where the students themselves set up the project topics. On the other hand, CERN ran entrepreneurial student projects with a specific technology as foundation for innovation. The student teams would use a market study -driven strategy to find an application area for the given technologies resulting in a technology push approach.

In the case of the IfC course, the innovation stemmed from pre-discovered needs framed by the partner organizations. The hypothesis was, that the students would find real world challenges as compelling starting points for projects and that the challenges would highly motivate them to work on the issues. The structure applied in IfC was a novel one for most of the course organizers and it wasn't clear how it would work compared with the other two models.

Hence, the authors of the paper created an online survey tool in order to track the opinions of the students and to see if they preferred technology, need or a self framed topic as a starting point for an impactful innovation project. Surveying the students provided some insight into how the different starting points varied from the students' perspective before and after the project.

Methodology and data collection

The students (n=48) were presented with an online survey regarding their experience twice: once post kick off week (February) and once post project (July). These two points allowed for tracking the change in the student's thinking and learning during the project experience. The first survey was answered by 31 individual students and the latter by 38. Since the answering was kept optional, some of the students did not provided material for all the points and this is why data presented in the results has an altering amount of replies.

A bit over half of the students had not done projects like this previously, while roughly 30% had some experience and 10% had substantial experience of project work. Majority of the students had varying engineering backgrounds on PhD or MA levels (roughly 85%), with some business (20%) and design (10%) backgrounds. Majority of the students had an Italian background (80%) and the rest were from other cultures (20%). Roughly one fourth of the participants were female and the rest male and the average age of the participants was 26 years.

The students were asked, if they would prefer a challenge starting from the technologies at hand (technology push), a challenge framed by an expert organization (need pull), a challenge ideated and put together by their teams or an open option “Other”. Each individual was allowed to select only one choice out of four. They were also asked why they preferred a specific option in an open text field format to get clarifying comments and qualitative data on their choices. Additional questions linked with the challenges were also posed regarding e.g. how open the students felt the challenges were or how easily the students felt that the technologies could be applied in their challenges. Here Likert scales from one to five were used to get an overview of the students perspectives.

The gathered data was analyzed by comparing changes in opinions between the starting and the end of the project. Correlation analysis was also run in order to find factors that might explain the opinion formation.

Two of the authors of the paper were responsible for challenge framing together with the expert organizations, framing pedagogical interventions as well as coaching the teams. These forms of interaction provide an additional layer of insight into some of the results presented next.

From a need preference to a balanced point of view

As can be seen in Figure 1, in the beginning of the project almost half of the students preferred to have a need based challenge setting. Second most popular view was to have the team's frame their own challenges (29%) and third most popular was to have technology to kick off a project (13%).

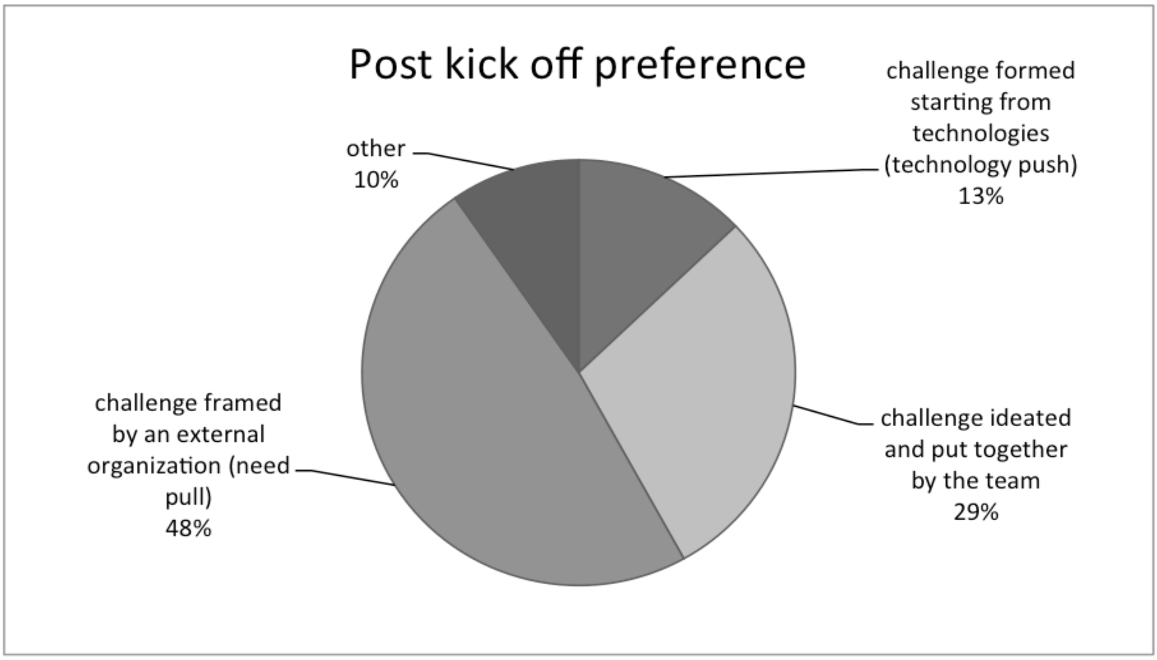

Figure 1: Innovation for change students opinions post kick off (n=31)

Many of the students expressed that they preferred need pull since they wanted to work on actual real world problems and also because they wanted to work outside of their own comfort zones as many of them were used to challenges starting from a technology. As one of the students explains, “I think that choosing your own challenge would have meant to start working too much within your comfort zone. Also, technology push would have meant too much of an indication from the technology developers on how to use it, and would have been a much less creative project.” Most of the supporting arguments for self defined challenges were linked with higher levels of motivation and ease. One of the students expresses, that “getting to work on our own ideas would be highly motivating and that it wouldn’t have been so demanding trying to understand a foreign problem field.” Another states, that “It would probably be easier to feel committed and have original ideas”. Some of the students who preferred technological starting points saw it as a prerequisite for a good solution: “We would have started from a clear technology base and we could have thought about innovative applications”.

As can be seen in Figure 2, the opinions had somewhat changed during the five-month project. The need pull approach lost 22% in popularity where technology push gained 20%. Self-defined challenge gained 2% more votes when other suggestions stayed at a steady 10%.

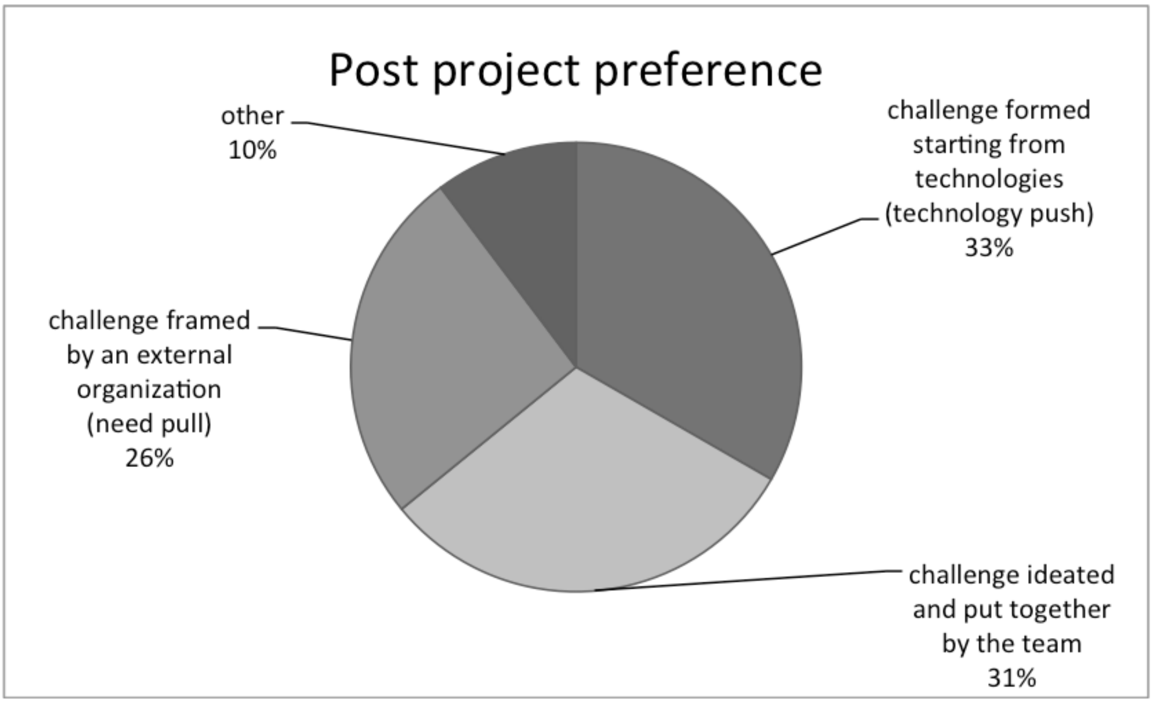

Figure 2: Innovation for change students opinions post project (n=38)

The students felt like that having a feasible technology to start from would really help the team to focus on the innovation part of the project. “Given the time constraints of the program, having the technology would allow teams to spend less time in developing a technical solution and more time in finding creative ways to solve challenges of their choice” one of the students writes. Another mentions that when starting from a technology “a solution already exist and you just need to find the best way to sell it.” As an alternative viewpoint, one of the students felt like the technology would allow them to have “more fantasy”. The reasons offered for selecting a need based approach were more scarce, though one of the students remarks, that “the world works "need-pull". Many wonderful technologies are there and we don't know how to use them or how to make them profitable. I don't agree with the idea that technology will save the world.” Some of the students wished a bigger challenge pool to choose challenges from. The ones wishing to do their own idea selection were still aware that it might be difficult to decide on one common project idea amongst the team members. “Although choosing our own problem to solve would have been nice, we would have lost too much time in this process. Having an already existing big problem from a company quickens things a lot” one of them declares.

In addition to the previous question, the students were asked how open they felt the challenges were (from 1=Very open/wide to 5=Very closed/specific) and also how easily they felt that the technologies could be pulled into the challenge frames (from 1=Very easily to 5=It would be very difficult).

Before the project the students felt on average that the challenges were slightly more open (average 2,4) than after the project (average 2,7). Their understanding of the challenges might have changed, since they learnt about the depth of the problem space they were operating in. After the project the students felt like it was slightly easier (average 3,8) to bring technologies to the project frame than before the project (average 3,6). This might be due to the fact that they gained a better understanding of the technologies they had at hand during the working months.

Applying Pearsons correlation coefficient, a correlation was found (p=0.032) between how open the challenges were seen and what was the preferred starting point. On average, the students who wanted set up their own challenge saw the existing challenges to be more open (3,1) than the ones who preferred existing technology or need as a starting point (2,4). A correlation looking at different teams was not found, which can also be explained by the small number of recipients (4-6 students per team). Seeing the challenges possibly too wide and difficult to narrow down might result in the students preferring to set up their own challenge. All in all, convergence amongst the team members was mentioned on several occasions in the research as one of the most difficult points in the project. No correlation was found between the continuing and discontinuing project teams regarding the openness of the challenge or the starting point of the challenge. This might imply that the challenge setup is not crucial regarding the success of the projects.

Discussion

The research results demonstrate that the students had a slight preference for need based challenge framing in the start of the project. However, by the end of the project they were fairly evenly divided between the need, technology or self defined challenge approaches. Based on this survey it is, hence, impossible to indicate which of the starting points is the preferred way to frame a project. However, some evidence was gained to support the hypothesis, that the students would find a need based challenge framing motivating as many of their comments contained a notion of this.

Though making a recommendation for challenge frame selection is not supported by the data, we can speculate over the reasons for favoring a specific options as the students provided some qualitative data on what their decision making bases were. Some of the students mentioned being accustomed to a technology push approach though being novices in projects starting from a self defined challenge or technology. The preference for need-based approach in the start might be linked with idealization of the approach or attraction towards novelty. The shift away from the need-based approach might be due to the fact, that the students now had the experience of the difficulties of need-based approach first hand. They could maintain a rosier image of technological or self defined challenge approaches, since they were not applied in the projects. Interestingly motivation was mentioned by the students to be highly important in all three cases. Having a difficult access to technology was mentioned to be demotivating, where both self defined and need based challenges were mentioned as being motivating. Originality of the ideas was also mentioned as a supporting argument regarding both technology based and self defined projects. It seems, that there is some kind of agreement on the important factors (motivation, originality) but how they can be brought into a project seems to divide opinions (technology, self defining).
Beyond this speculation, the test itself also needs improvement to offer valid results. For example, the test did not include an internal consistency check and each question was only asked once and one way from the participants. To fix this, a question could be added regarding e.g. which would be a *bad* starting point for innovation. In order to improve the generalizability of the research construct, the test should be done with different cultural and age groups. Now the sample had a strong bias towards engineering. The results might be different in a group that had mostly design backgrounds.

Regarding future research, it would be interesting to run parallel projects starting from a technology, need or self-defined challenge, and apply a similar survey comparing the results.

Alternatively, the teams could select their preferred starting point of the three in the beginning of the project and could be then surveyed based their experience and project outcomes. This would create more challenges for the arrangements the course regarding e.g. recruitment of external organizations as collaborators. It would also be interesting to ask the students about their opinions a year after the project ended to see if they have had deeper reflection on their experience and how the opinions might have shifted.

All in all, in order to gain more robust results, more data from alternating structure should be gathered and cross-checked to get a better understanding of the projects and also on how context-specific the results are. Since the design thinking process is about incorporating technological feasibility with desirability and need based thinking, perhaps the challenge could also be a combination of different elements to start from.

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