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The Future of Project-based Learning for Engineering and Management Students: Towards an Advanced Design Thinking Approach

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ME 310I: The Essential Elements of New Product Development: Business and Industry Perspectives

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The future of the project-based learning for engineering and management students. Towards to advanced design thinking approach

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1. Introduction

At present, project-based education is one of the most significant and in-demand professional skills. Project-based education is the important part in the whole studying process as while exactly working at the project the students gain skills of solving the practical important tasks, get the knowledge and skills, which can be used in further educational and professional activity [1],[2].

To tribute the significance of the project based methods, both in engineering and management fields, universities include teamwork and group trainings as part of the curriculum for undergraduate and graduate students. As part of project-based experience, students will receive industry specific knowledge and skills and also will learn the effective group communication, which significantly related to the success of the project. In most cases, students participants have limited or do not have any experience of teamwork, and this seriously complicates the implementation of the project, leads in some cases to formal participation of the students in the project and / or poor quality of the fulfillment projects [3],[4]. Project based education is also required well proved methodology to support the process. Creativity, team working, commitment to people, curiosity and optimism are the main elements of the design-thinking methodology (DT) [1],[5], which is often used for searching the new decisions of the existing challenges. DT methodology traditionally based on the use of different opinions, group discussion and communication. Our experience was to bring engineering and management students to work together for solving complex interdisciplinary issues using SAP Next-Gen program and SAP Next-Gen Lab concept.

2. Design thinking

To begin with we should evaluate the history of the design-thinking methodology. For the first time, some elements of Design thinking method we can find in it was written in the book "The Science of the Artificial" by Herbert Simon in 1969. The term entered machine engineering and architecture started developing. The concept of design thinking was generalized by Professor of Architecture Brian Lawson in his work "How Do Designers Think" in 1980. The faculty members at Stanford University introduced the methodology into education [1] . David Kelly introduced the method into business [5].

Developed at Stanford University, this method helps to develop the skills of active involvement of leaders in solving the practical, real problems in the learning process of the basic principles of the design thinking, such as: a person-oriented approach to creating innovations, prototyping, etc. Formation of self-confidence and in its team, the comprehensive consideration of those goals that face managers, the real needs of the employees and organizations, allows solving the significant tasks using special modeling methods.

Design Thinking is a set of worldview attitudes and methodological guidelines that took shape at the turn of the millennium as a reaction to the emergence of a new economic system with the inevitable reassessment of the values of the previous economy. We can also describe Design thinking as a special way of thinking, the ability to find something new and creative among already known to everyone. Design thinking unites a team of people, properly organized space and supporting process for creating the innovations.

We can also say that Design thinking is a **method and way** of thinking that helps people to solve complex problems or achieve complex goals in conditions when something is not known and the solutions are in the field of uncertainty, that is, at the starting point there is no obvious solution and the whole path. This methodology is especially relevant in the development of new entrepreneurial and innovative projects both for engineering and management students, since it allows going beyond the standard thinking when it is necessary to develop a new product, service or technology.

The SAP Next-Gen program [6] is an innovation platform for the SAP ecosystem enabling companies, partners and universities to connect and innovate with purpose linked to the UN Global Goals. The SAP Next-Gen program provides unique opportunities for partners and your communities to join the conversation on exponential technologies, digital futures, and "innovation with purpose" linked to the UN Global Goals with next-generation thinkers. SAP Next-Gen Lab is as essential element of SAP Next-Gen program. Design thinking is integrated

part of project based education at SAP Next-Gen Labs. The main stages of Design thinking process described below.

3. Design thinking stages

Apologists of design thinking are IDEO company, which in order to demonstrate the capabilities of this approach, in partnership with SAP company co-owner, Prof. Hasso Plattner initiated the creation at Stanford University of the so-called d.school (similar to the business school). The continuation of the ideas and tools developed at Stanford was further developed in Potsdam, at the HPI School of Design Thinking

The whole concept of the program is based on and, at the same time, it is the basis of the "*Silicon Valley work style*". The classic version of the process of design thinking provides an opportunity to comprehend the mystery of the innovative thinking through the several inter-related stages:

1. "Understanding" - understanding of current complexities and their context.
2. "Observation" is an attempt to look at the problem through the eyes of the final user,
3. "Definition of the point of view" - a brief formulation of the problem that we will solve and for whom we will solve it,
4. "Ideation" - the development of the ideas,
5. "Prototyping" - the creation of the prototype,
6. "Testing" - testing the solution with the invitation of the potential final users.

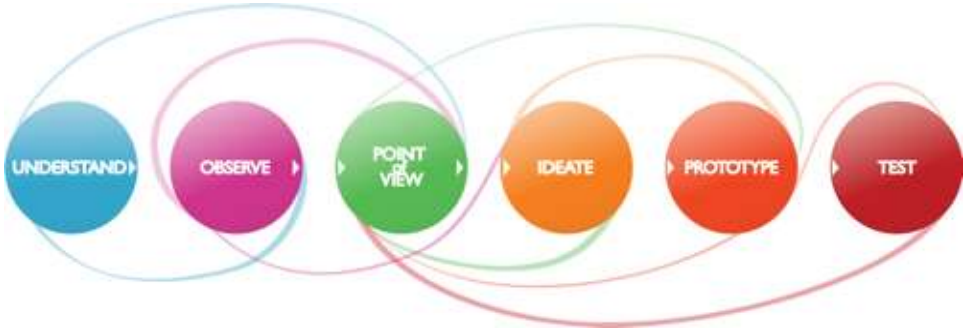

Fig. 1 The Six Design Thinking Phases

At the first stage, according to the method of design thinking, the students deeply study the problem. It is very important to achieve a common understanding of the task between the team members. The various methods are used for this, including brainstorming, charetting (a method for quickly understanding of the project tasks), etc. The result of the first stage should be a specific wording of the project goal: what, and, most important, for whom we do, this includes a detailed description of the user, his problems and needs, and the identification of the restrictions.

The second stage of work at project includes the search for so-called "insights" ("the essence of the problematic situations"). There are many thoughts, but the innovators are able to filter what is happening, look at the world with other eyes, not forgetting about the orientation towards a certain target audience. The purpose of this stage is to gather additional information about the problem and the available solutions, and to identify the constraints that can restrain the solution. The result at this stage is achieved through both the simple observation and through the other people's experiences. The main task of this stage is to understand the reasons why people act in this way, and not otherwise. Why they buy exactly from those competitors, why they look for in the search line with the help of those words, what problems and tasks they face at this moment, what they feel and what they think. Understanding is the stage of gathering primary information, which after that still needs to be properly processed, classified and used to gain understanding. Understanding, or empathy, as an integral component of this stage, allows putting yourself at the place of the user, the potential client. At this stage the better the consumer will be studied, the more likely that we will be able to develop and offer him exactly the product that will best meet his needs and expectations.

The next thing that potential developers need to understand is an understanding of the focus of the problems, the necessity of the clear vision of the difficulties. The investigation of target users needs is added to the "insights" concluded from the previous two stages, and within these areas there is a clear target for the shot at bull's-eye of the chosen concept. That is, after the information about the problems in this or that area is collected, it needs to select a focus. The focus in this case is the combination of the "task" and the "person" in one sentence, that is, the formulation of the task, at which it is planned to work, focused on a specific user. In order to create the innovation, we need to solve what is not solved by the others, and everything else can be copied. That means, to focus on those problems and tasks that are considered as unsolvable at the moment, which no one solves and considers as necessary evil. It is in them the greatest potential for design thinking is hidden. By adding to this the analysis of the exter-

nal environment, we can establish the constraints that could restrain the solution of this problem. All of it forms a point of view on the problem, in the methodology of design thinking it is called Point of view. The clearer and more detailed it will be formulated, the clearer and easier it will be to develop the solution for this problem. When the goal is clear, it is easier to achieve. This is also important to understand at the work on the project.

Finally, after determining the subject of careful attention, one can proceed to the generation of the ideas in the form of brainstorming with the advancement of all conceivable and unthinkable solutions of the chosen problem. The task of the fourth stage is to generate as many as possible ideas for solving the outlined problem of the previous stage. Wherein there is no need to concentrate on the obvious solutions, as it may lead away the attention of the team from the creative decisions and decrease the likelihood of the innovation. It should be minded these ideas are not final and there is always a possibility to create new one and more effective solutions, turned back to this stage at any moment.

Before starting to develop the prototype, it needs to select 2-4 ideas. As a rule, ideas are selected by voting. Every participant can choose, for example 4 ideas by the following characteristics:

- best for user;
- mad;
- reasonable;
- favorite.

Further, the ideas selected in voting are embodied in prototypes. Prototyping is an iterative process. In the course of it, one can generate new ideas, improve old ones, get a clearer vision of the problem and solution. A prototype can be everything that can interact with:

- physical prototypes;
- sketches on paper;
- software prototypes;
- role scenarios, etc.

The main thing is that the user can get his experience from the prototype, "play" with it, feel in action. And the team collects their observations of user interaction with the prototype for its further refinement [4].

The final stage is testing of the selected ideas. Of course, the ideal variant is testing in the real conditions, but one can try to create the environment similar to the reality (for example, through role-playing games). At this stage, it is important to get feedback and make appropriate adjustments (if they are, of course, needed). We can say that the testing is the phase of

getting feedback about the solution. During testing, the task is also checked: whether it was formulated correct.

Despite of well-defined Design thinking process there are a growing concern for the last few years about effectiveness of Design thinking specifically to support corporate creativity and innovation [7], to the problems of disconnection between design thinking and conventional business processes/corporate culture issues [8].

In our paper, we would like to introduce the use of the advanced design-thinking, approach in organization of multidisciplinary students' project work. The main elements of Advanced Design thinking approach in relation to DT's essential elements: People, Space, Method/Processes are described below.

4. Towards to Advanced Design thinking approach.

The key philosophy of Advanced Design thinking is use interdisciplinary approach, actively use corporate experience of the past, business history and corporate narrative in dealing with corporate culture complexity. The DT's essential elements: People, Space, Method/Processes will be reviewed to understand better further developments of DT approach.

4.1 People

One of the key principles of design thinking is the empathy - the ability to look at the world through the eyes of other people, to understand their needs, desires, and the tasks they face. That requires the cardinal transformation of the consumption culture from the modern . In the process of design thinking, the empathy is the necessity to understand, so to speak, the vocabulary of people, because in this way the respect is shown to them-it shows that they are spoken in one language. That's why it is also very important to have interdisciplinary team of students, with diverse education and culture backgrounds. In our research, we are using SUGAR Stanford ME310 course as visible example of two teams (US based) and (International based) will need to work together. Now, more than twenty Universities from US, Germany, Switzerland, Japan, China, countries of Latin America are part of ME310 community. It is unique opportunity to work on real challenges from Industry. ME310 project has length 9 months, mostly graduate level oriented and provided significant intercultural experience for participants. ME310 course dynamic characteristics are also part of research conducted at Stanford DesignX Lab, conducted at ME310 loft and Design Observatory (DO) at

Center for Design Research [9]. Design Observatory is a core instrument for conducting research in the field of design theory and methodology and created with the goal of conducting designer's information data collection, analysis procedures associated with observation of designers. Despite of significant results , published in multiple papers and books, more attention required to understand the fundamental issues behind of team culture, communication and language issues [10].

4.2 Space/Memory

Space is one of the key elements of Design thinking. It is not only also the place of team work, but collaboration and makers space. Advanced design thinking will require common ground for developing campus based Design thinking Spaces. Stanford ME310 Loft and brand new SAP Next-Gen Lab at Plekhanov University are presented below.

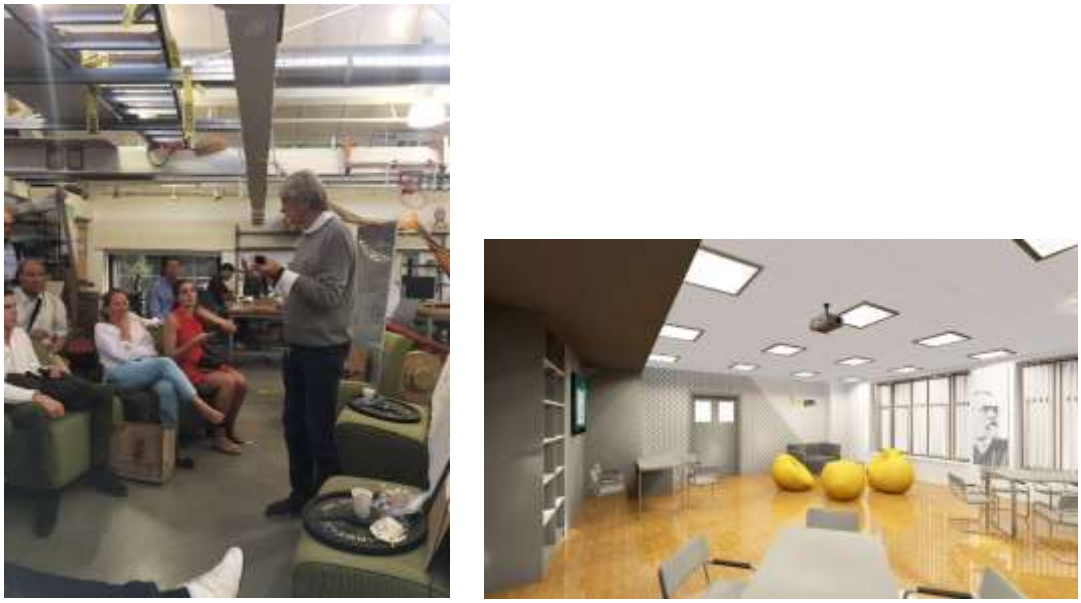

Fig. 2. Design thinking Space. Stanford ME301 Loft at Stanford University and SAP Next-Gen Lab at Plekhanov University

Despite of physical space design difference, it is strong cultural link between Stanford Loft and SAP Next-Gen Lab concept (inspired by Stanford). In fact, we are helping students to be creative, to offer an informal atmosphere, supporting creativity and making. In order to help academic institutions to design SAP Next-Gen Lab, SAP Next-Gen defined the list of recommendations based on Stanford ME310 Loft, created the standard design templates, which

Universities can use. As the result, the time of opening of Next-Gen Labs reduced significantly. Such approach of standardization of Design thinking Labs can be also be implemented in business environments, working together with facilities departments at established companies will help to bring the same standards to different corporate offices in different countries.

Another important element of advanced design thinking process often neglected is the concept of proactive use project's historical data, especially during initial stages of design thinking process. Such approach to use historical methods as the way of analyzing past projects artifacts and essentially will be the foundation of extensive project specific knowledge base. As an example of such approach is a very large historical engineering prototypes of Paper bikes - data collection at Stanford ME310 Loft as part of Paper Bike Challenge, annual warm-up design exercise for ME310 Student teams. The main rule is to create a vehicle made of paper to participate in competition. Another approach to use history as motivation was introduced at Plekhanov University, to bringing University history inspiration to the SAP Next-Gen Lab, by adding University Founder, Mr Aleksey Vishnyakov's lithography to the Next-Gen design. Such approach will be, in fact, visible example of interconnecting the Past and the Present, will clearly help to inspire a students.

Fig. 3. A link to the Past at Stanford University (Paper bike collection form the past projects) and SAP Next-Gen Plekhanov University (University Founder's Lithography)

4.3 Method/Processes

Advanced design thinking will also require to have a look in details to the key elements of Design thinking process. From our project experience, we decided to highlight a few elements of the proposed methodology which we are using during Academia – Industry collaboration projects.

4.3.1 Storyboards

One of the integrated parts of SAP Next-Gen Labs is use of Storyboard technique. Storyboards are a powerful way to show the value of ideas and product visions in their context of use. They make proposed ideas/concepts better understandable. We are using SAP Scenes, developed by SAP AppHaus Heidelberg, Germany. Scenes is a tool and a method to create storyboards about products and services fast, collaboratively and iterative [11]. It empowers business leaders and professionals of all industries to shape their ideas and scenarios in the form of fun illustrative stories without the need of refined drawing skills. Such approach is also fully applicable for students projects, will allow to share student's ideas with industry sponsors. Scenes includes a set of pre-defined illustrations that can be physically or digitally combined in scenes to create a visual story and presented below.

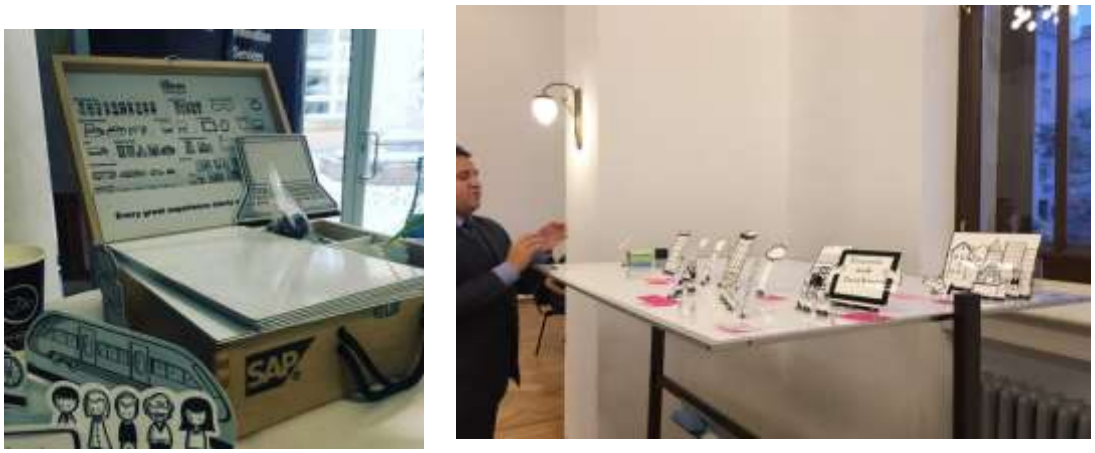

Fig. 4. Using Scenes developed by SAP AppHaus Heidelberg

4.3.2 Team structure

According to traditional design thinking approach, the team is formed in such a way that the people who perform different roles should necessary present in it. The nominal number of roles in the team is 7 persons, in practice there may be more or less of them for 1-2 people, but it is desirable that in the team should be not more than 10 people, since a large group is more difficult to manage. From our experience, the nominal number in the team is 4 persons, if case if we have two teams (US based and International teams) in the team should be no more than 6-8 people in total.

Thus, an effective team is formed, where each participant, performing his role, contributes his individual (personal) significant value to the project. It is important to note that organizing the students project work, it is important not only correct assigning of the roles and tasks, setting goals, explaining evaluation criteria. For interdisciplinary team, ideally, we need to bring not only engineering and management students, but to have students relevant to specific industry cases – biology, medicine, chemistry, etc.

Another important element is to have intercultural coach as part of overall structure of project advisors team – such person will provide key support to diverse teams in order to eliminate communication inconsistences and to harmonize intercultural dynamics.

The use of the methodology of design thinking in the organization of students project work allows you to coordinate, direct, correct the work of the students at every stage of the development of their group project. The students learn to deeply explore the problem through the observation, interviewing, they can form a detailed portrait of the user - their final consumer, to learn and describe in detail his characteristics, needs, problems. Correlating it with the already existing experience of the solutions and constraints, to form a clear vision of the problem situation.

4.4 The Sustainable Development Goals (SDGs). From Human-centered to humanity centered Design Thinking

4.4.1 The Sustainable Development Goals (SDGs) and humanity centered design

The Sustainable Development Goals (SDGs) [12] are a 17 global goals set by the United Nations. The SDGs cover a broad range of social and economic development challenges. These

include poverty, hunger, health improvement, better education, climate change, gender equality, water, sanitation, energy, environment, etc"

We believe that advanced design thinking approach should cleary elaborate the role of global sustainable development and to move from human – centered approach to humanity-centered design process. We need strongly address global issues and to design our world as better place. Example of such projects conducted at Stanford in partnership with SAP and UNOOSA

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4.4.2 Stanford – UNOOSA-SAP Project overview

The devastating impacts of natural disasters cause loss of lives and property around the world. To avoid that sustainable development is undermined by natural hazards, disaster risk management based on effective early warning systems, improved understanding of risk and better information about the onset of disasters is crucial. Space technologies such as remote sensing for Earth observation, satellite-based telecommunication and global navigation satellite systems can contribute to more effective disaster risk management and emergency response by providing accurate information about the risk and onset of disasters, improved risk assessments, early warning and disaster monitoring. To facilitate the access to space-based information relevant to disaster management, the United Nations General Assembly established the UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) [13] in 2006 as a programme of the United Nations Office for Outer Space Affairs (UNOOSA).

UN-SPIDER is mandated to provide access all countries, and especially developing countries, to all types of space-based information in all phases of the disaster management cycle including prevention, preparedness, early warning, response and reconstruction. The UN-SPIDER Knowledge Portal acts as a knowledge base on space-based information and solutions to support risk and disaster management and aims to facilitate the discovery of relevant data and information and to support users in processing and mapping the data.

The United Nations system is intensively collaborating with SAP Next-Gen, SAP Academic initiative enables SAP customers to seed in disruptive innovation and accelerate their SAP software journeys through connecting with academic thought leaders and researchers, students, startups, accelerators, venture firms, and other partners in the SAP Next-Gen innovation community. Current Project at Stanford include two groups of MSc students which Define, Ideate and Create a prototype of future of UN-SPIDER Knowledge Portal. Some possible defined:

- Evaluate an effectiveness of current portal functionality and to develop software related roadmap of covering possible use of knowledge management solutions, Big data, Machine Learning, IoT, AR/VR
- To develop UN-SPIDER Knowledge Portal Mobile Platform
- Social networks role, how to utilize social networks opportunities

Advanced Design thinking methods are part of Stanford-UNOOSA-SAP team's philosophy. Stanford students are only working for better understanding of current trends in Knowledge Management, Mobile Platforms, Big Data and Machine Learning, also intensively using humanity centered design and have real passion to help others around the Globe and to Change the World. This project was proposed at UNOOSA Workshop in United Nations Workshop on Human Capacity-Building in Space Science and Technology for Sustainable Social and Economic Development in 2017[14]. International team collaboration plan of actions in underway in order to work closely with SAP Next-Gen Labs from developing nations in order to improve disaster management global capabilities.

5. Conclusion and future work

Design-thinking approach for organization of multidisciplinary students' project work was introduced. SAP Academic Initiative - the SAP Next-Gen program and SAP Next-Gen Lab were briefly explained. Design thinking is integrated part of project based education at SAP Next-Gen Labs. The principles of Advanced Design Thinking approach for SAP Next-Gen Labs for both Management and Engineering discipline students were presented.

Summarizing all the above, we say that the advanced design-thinking technique allows making the work at project in the team the most effective, since it is a system approach in the developing the solution of the problem, combining the teamwork, innovative approaches, creativity of thinking, active communication, openness, design, visualization. All of this promotes to the formation at students the valuable communication skills, entrepreneurial skills, oratorical skills, obtained in the process of solving the real problems received from the external environment. Thus, the students acquire the practical skills, and experience that will be in demand among them in further educational and professional activities.

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