2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34561

A Context-centered Visual Tool for the Design of Engineering Education Solutions

Ms. Imane Aboutajedyne, Sidi Mohamed Ben Abdellah University, Fez (Morocco)

Imane Aboutajedyne is a Ph.D. researcher in Engineering Education at the Faculty of Sciences and Technology of Fez, Sidi Mohamed Ben Abdellah University, Morocco. Her current research focuses on the development of an innovative design approach to engineering education.

Dr. Yassine Salih Alj, Al Akhawayn University

Yassine Salih Alj received the Bachelor's degree in microelectronics from the University of Quebec at Montreal (UQAM), Montreal, Quebec, Canada, in 2001, and the Master's degree in electrical engineering from the École de Technologie Supérieure (ETS), Montreal, Quebec, Canada, in 2003, and the Ph.D. degree in Telecommunications from the National Institute of Scientific Research – Energy, Materials & Telecommunications (INRS-Telecom), Montreal, Quebec, Canada, in 2008. He served as a research assistant at the Telebec Underground Communications Research Laboratory (LRTCS) from 2005 to 2008, and then during 2009 as a Postdoctoral Fellow at Poly-Grames Research Center, of the École Polytechnique de Montréal, Montreal, Quebec, Canada. He is currently working as a permanent faculty member at the School of Science and Engineering (SSE) of Al Akhawayn University in Ifrane (AUI), Morocco. He has published over 50 publications and has been actively involved in IEEE events for the past five years, where he chaired and served as Technical Program Member or as distinguished reviewer for over 100 conferences. His research interests are in the areas of Wireless Communications, Indoor Positioning, UWB (Ultra-Wideband), Digital System Implementation, GPS (Global Positioning System) and Engineering Education.

Prof. Ahmed Aboutajeddine, Sidi Mohamed Ben Abdellah University, Fez (Morocco).

Aboutajeddine Ahmed is a professor of mechanical engineering at the faculty of science and technology, Fes, Morocco. He is involved in many projects for improving engineering education in Morocco. He holds a PhD from the University of Sherbrooke, Canada.

A CONTEXT-CENTERED VISUAL TOOL FOR THE DESIGN OF ENGINEERING EDUCATION SOLUTIONS

Abstract

In a rapidly changing world, it is crucial to empower engineering students with 21st century skills. This can be achieved by the design of effective educational solutions that equip students with these sought-after skills. However, since the delivery of education cannot be isolated from the environment in which it takes place, the design of effective solutions might be influenced by diverse factors related to the context of students, instructors, and the institution as a whole**.** Therefore, engineering educators have to consider global contexts to ensure the development of educational solutions with the seed of a successful implementation. Still, the tools used in instructional design often fall short of capturing the limitations, perspectives and contexts of students and the institution. In addition, existing context analysis tools do not include the alignment of context elements with the intended learning outcomes, teaching/learning activities and assessment tasks. Therefore, new context-centered tools are needed to enable educators to have a broad vision about influencing elements and facilitate the alignment of instructional solutions to critical context factors. In this regard, a visual design tool was developed to help educators create effective educational solutions that are aligned with the student environment and the institution context. The proposed canvas builds on conceptual frameworks in education and user research principles of human-centered design, and merges them with themes from the environmental analysis to define the elements of the boarder context in which education is designed. This visual representation helps in generating and juxtaposing key educational influencing elements that can guide the ideation of effective solutions. Moreover, this visual tool enables taking into account contexts of different categories of students and, thereby, helps design inclusive learning concepts that will contribute to the emergence of a more diverse skilled engineering workforce.

Keywords: Engineering Education, Human-centered design, conceptual framework, context-centered design, visual design tool, inclusion.

Introduction

Creating value for people is crucial in major fields of human endeavor. Indeed, innovative solutions are designed to meet the specific needs of people in a particular context [1]. In engineering, for instance, scientific knowledge is applied to develop products, services, and systems in order to solve problems that affect the quality of human life. Along with addressing this core value, solutions need to be technically feasible and economically viable [2]. Similarly, in engineering education, educational solutions need to bring value to students in terms of 21st century skills acquisition. Besides, solutions also have to provide a desirable human experience. In fact, for a meaningful and successful educational experience, appropriate learning activities and assessment methods should be aligned with the learning goals of students. Moreover, solutions should be implementable in the context in which education takes place [3]. Hence, emphasis has to be placed

on developing human-centered solutions that satisfy the needs of the student and education stakeholders while considering critical factors of the education environment.

Therefore, to develop innovative solutions in education, engineering educators –as designers of learning [4]- need to conduct holistic research about the student and the global context of education at the early stage of the design process to make decision-making easier in the ideation stage. For that, educators need to not only understand the student environment and the institutional context where education occurs, but also gain knowledge about best practices in teaching and assessment. In view of that, Human-centered design offers the ability to collect relevant information through a deep user research in the problem identification stage [5]. However, to define insights for the ideation stage, collected data about the student, the context, and education practices need to be synthetized. On the other hand, the constructive alignment principles allow educators to explore the right combination of educational practices and align them with the learning goals of the educational activity [6]-[7]. Thus, it is necessary to find a way to capture and connect relevant information from the user research, context analysis and educational practices. Similarly, the Input-environment-outcome model (IEO) provides a conceptual approach for defining how the educational environment and student background are influencing the student outcomes [8]. The method is used to guide the assessment of activities in higher education. It is a way to evaluate the ability of the institution to develop the student skills and faculty capacity in a specific context. Hence, for measuring the program effectiveness, the model combines the student input variables (i.e., background, purpose…) and the learning outcomes, while taking into account the learning experience and educational environment (i.e. courses, teaching/learning activities, structure, facilities…) [8].

Building on the above-mentioned conceptual models, this work proposes a Context Canvas as an actionable framework to facilitate gathering information and finding correlations between the elements that influence the ideation of educational concepts. As a design tool, the context canvas aims to help educators move from the problem space to the solution space in the process of educational solution development.

This paper is organized as follows. First, overviews of conceptual models for design are recalled. Then, the rational and structure of the context canvas are explained and an example for use is illustrated. Finally, a conclusion is drawn.

Conceptual Models

In this part, we introduce the human-centered design approach and the constructive alignment principle.

The Human-centered design approach

The use of human-centered design (HCD) for addressing complex challenges has seen an increasing interest in various domains during recent years. Its ability to improve the experiences of end-users - employing consumer-oriented processes and methods - is gaining attention in education [4]. The design company IDEO originally popularized the application of HCD as a process for

value creation. The design approach aims to build what is desirable from a human point of view while considering the feasibility and viability of the solution [9].

HCD is a divergent design process balanced by convergent thinking [10]. As illustrated in Figure 1, its three main phases - inspiration, ideation, and implementation - allow the designer to explore the problem from different perspectives in the problem space, and encourage narrowing down the focus of thoughts in the solution space.

The inspiration phase offers tools to understand the problem and motivates the exploration of solutions. In this phase, designers conduct in depth research about users and document the findings.

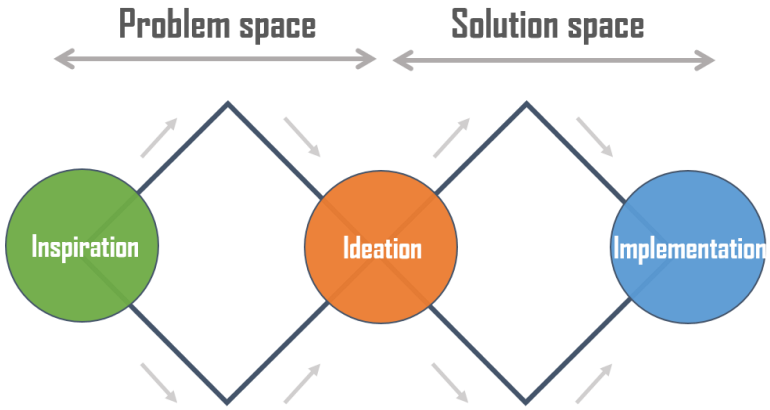

Figure 1: Human-Centered Design approach.

Collected information is clustered in themes and meaningful insights are intuitively highlighted. The user research provides the basis for subsequent step of the design process [11]. Actually, based on the insights, different concepts are generated, developed, and tested in the ideation phase to be finally led to the market through the implementation phase.

User research in HCD

The critical goal of user research is to enable designers analyze both the tacit and explicit needs of people they are designing for [12]. It motivates decision-making by providing comprehension of the design problem within the context of the target audience [5]. Empathy methods (e.g., observation, interaction, immersion), and secondary research (e.g., online search, literature…) offer multiple and accurate information about the environment of the design challenge. Designers have to extract fundamental meanings through the exploration of emerging themes or associated information [13]. Thus, a well-conducted user research and a proper synthesis are vital for the creation of applicable solutions that delight the user.

Decision-making in design

In literature, decision-making is defined as the process of choosing solution alternatives in terms of required goals and consequences [14]-[15]. In HCD, The transition from the user research to idea generation is a rational process balanced by intuitive thinking. In fact, designers rely on two complementary knowledge sources to guide the design solution. They use findings from the research and the contextual environment of the company (research), as well as knowledge from

accumulative experience (intuition) [16]-[17]. For either novice or experienced designers, intuition can be enhanced by expanding the knowledge base through reading, exploring analogies, etc. [14]-[18].

In the process of decision-making, designers have to first define which factors to consider and then analyze the causality between the factors. A holistic vision about the problem is needed to perceive how various elements fit together [19] - [20].

Constructive alignment

For a student-centered education that focuses on satisfying the needs and learning objectives of the learner [21], constructive alignment (CA), as illustrated in Figure 2, guides the creation of appropriate learning experiences trough the alignment of instructional approaches and assessment methods with the intended learning objectives (ILOs) [7]. CA aims to drive decision about the teaching/learning activities (TLA) that elicit a level of performance of the learning outcomes, and assessment methods that report students' performance [6]. Yet, it is necessary to have sufficient knowledge of the three components (i.e., learning outcomes, teaching/learning, and assessment practices) to create a learning concept. For that, educators have to define the learning objectives from the students' needs and conduct research about the best educational practices that bring out the defined learning goals.

Meaningful learning activities and assessment methods are essential for the success of a learning experience. However, the "meaningfulness" does not only depend on the type of the education practice, but also on the environment in which it is conducted. Hence, when choosing a TLA or assessment practice, educators need to take into account the context of use of this practice [22].

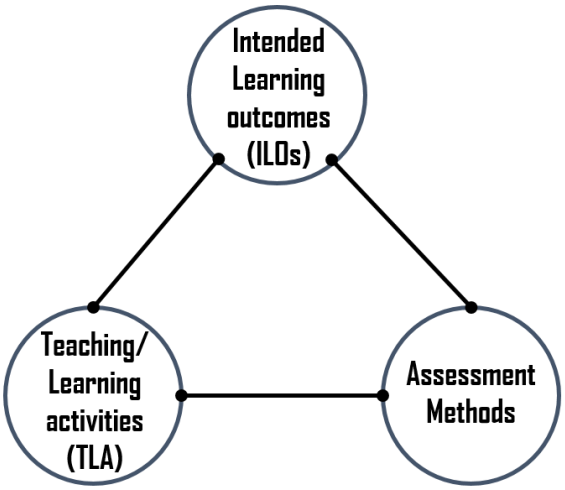

Figure 2: constructive alignment principles.

The context canvas

The transition from the research, in the problem space, to the ideation in solution space requires designers to keep focus on critical criteria for an effective implementation of the solution. For that purpose, this work aims to help educators keep sight of relevant elements for developing an optimal

solution that considers the feasibility for implementation and viability to the students and institutions.

Finding correlations and having a “big picture” of the challenge requires a cognitive effort for holding all the element in mind at once [19]. In this part, we present an actionable worksheet in form of a Canvas with specific blocks that guide educators in collecting relevant information from the user and secondary research, and support defining correlations that facilitate the generation of effective educational concepts. The visual tool seeks to offer an intuitive approach for establishing connections [18]-[23]. Moreover, the blocks of the canvas bring structure to the insights and provide a way to evaluate collected information. The canvas can be used by novice or expert educators and be applied in an individual or group setting.

Blocks of the canvas

The canvas supports defining the sought implicit and explicit knowledge about the educational context. It is composed of three main categories, as shown in Figure 3; the user context, the institution context, and the education practices. Each category is structured into blocks.

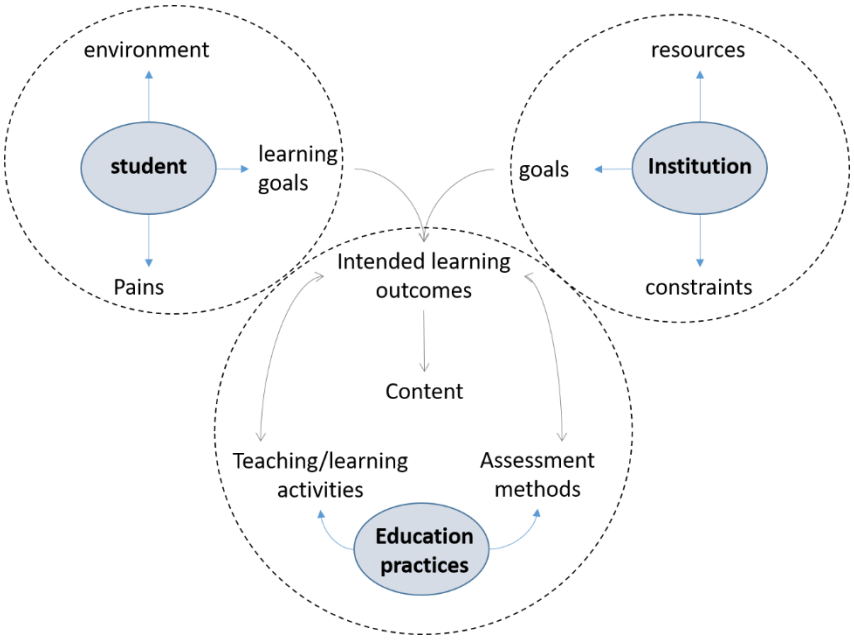

Figure 3: categories and sub-components.

The blocks shown in Figure 4, represent themes that might influence the development of an educational solution. Some themes for the context analysis of both the student and institution are inspired from three elements of the social, technological, environmental and political (STEEP) analysis for analyzing the environmental factors (i.e. Social, technological, Economic), and the Input-environment-outcome (IEO) model. Others that are related to the constraints are derived from the value proposition canvas [2]. Blocks of the education practices category represent the elements of constructive alignment. In the following, we explain the blocks of the three categories (i.e., user context, the institution context, and the education practices) and provide how the information could be collected.

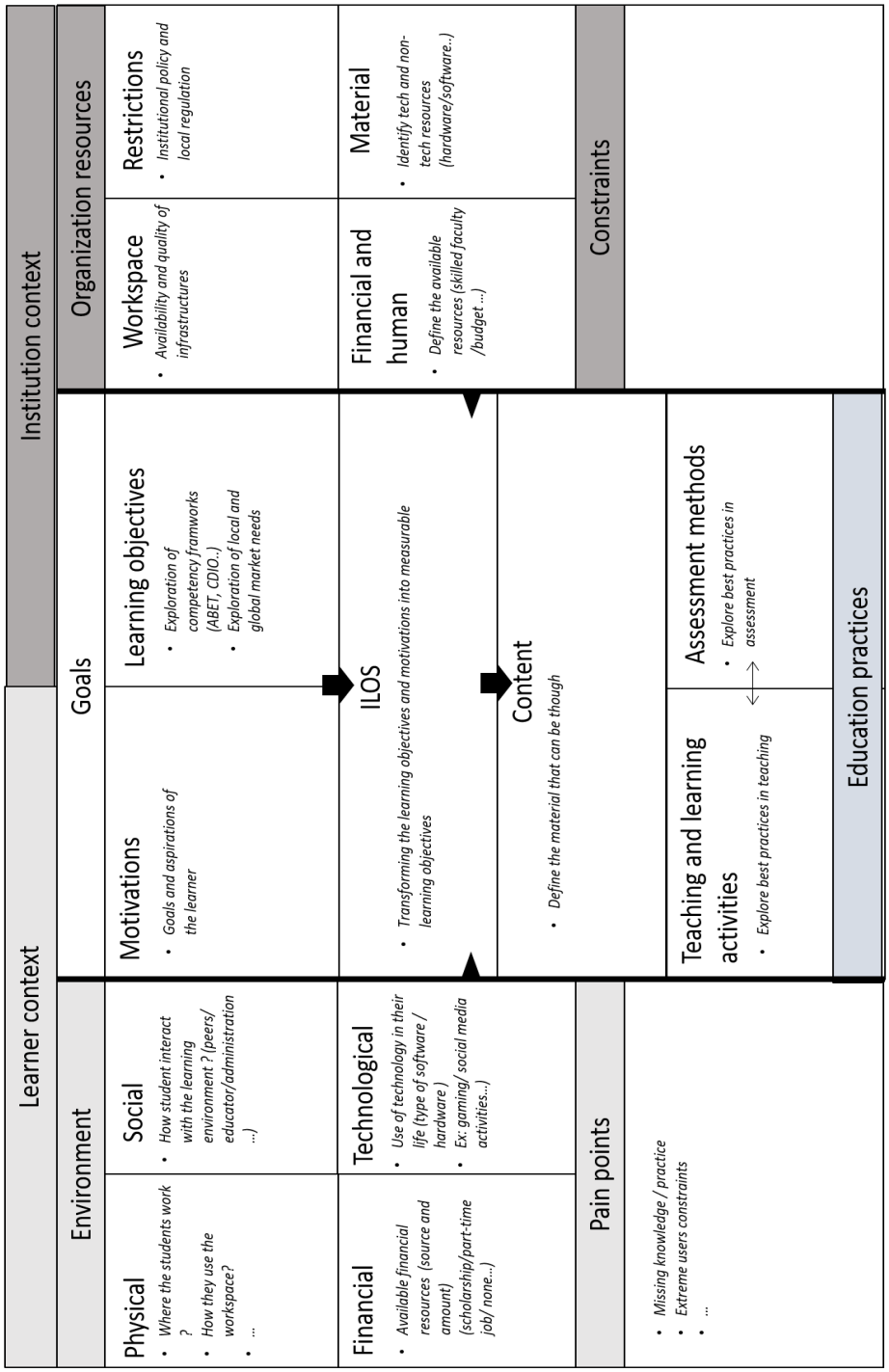

Figure 4: the context canvas

For the user context:

Three elements need to be considered in this part; the environment of the student, the motivation for learning, and the pain points of the students. We define the students' environment as the elements of the surrounding in which students live and act. The pain points are related to the frustrations, constraints and emotions that students experience [2]. To grasp sufficient knowledge

about the *environment*, and be able to detect their *pain points*, one must consider investigating the four following themes: physical facilities, social interactions, financial conditions, and technological culture.

For the physical theme, educators need to consider where students work, how the place is designed, how the workspace is used, what students like about the current space, and what alternatives they have. To get this information, designers can conduct observations or interviews with students.

For the Social aspect, educators have to understand the social behavior of students by noticing how they interact with their peers, professors and administration. An immersion exercise could be useful for collecting data for this theme.

Defining the financial conditions is crucial when it comes to generating appropriate learning solutions. For that, educators should know the income sources of students (e.g., Scholarship, part-time job, family finances, loan…), and the charges they have.

The technological culture is another aspect of the student environment that needs to be taken into account. For this research, one must identify the type of technology that is used by students, list the new trends in the market, and know how students use technology in their daily life.

This guided ethnographic research aims to bring to life the *pain points* of the students. Indeed, it is essential to highlight the constraints of extreme users (e.g., low-income, gap in the background knowledge…) to come up with inclusive solutions.

Moreover, special attention needs to be directed towards understanding students' motivation. For that, educators should define what students are willing to achieve through the program, what their dreams are, and how they plan to achieve their goals.

<u>For the institution context:</u>

In this category, we define three elements to take into account, namely, the organization resources, the learning objectives, and the constraints. Indeed, education designers seeking implementable solutions must tap into the available *resources* of the institution and know the local conditions. For this category, we identified four themes that could be considered: the workspace and facilities, the local restrictions, the financial and human resources, and the existing material.

The workspace block requires identifying the physical infrastructure and digital means that the institution offers for working. For this block, we suggest documenting the research with pictures of the workspace.

Educators should be informed about the local restrictions that are applied under specific circumstances (e.g., pandemic restrictions). Hence, they have to outline the local policy and important regulations.

Since developing solutions requires both financial and human resources, it is necessary to define the available budget, scholarships, and prizes, and gain knowledge about faculty skills, attitude, and willingness/preparedness to implement change.

Identifying the existing material, such as basic and advanced prototyping tools (e.g. 3D printers, CAD software) is also important for having an overall overview of what means can be used when developing the educational concept.

Every institution attempts to prepare its students to the world challenges. Therefore, educators should consider defining the local and global trends in the job market, and explore existing competency frameworks (e.g., ABET, CDIO syllabus, ...) to identify the *learning objectives* that fit the institution's vision.

It is also essential to be mindful of the constraints of the institution. Hence, educators should highlight critical limitations that need to be considered (e.g., lack of financial resources, local lockdown…). Information for this block would be synthetized from the research about the resources.

For the education practices:

In this category, we consider that three themes can guide educators in gathering information: Teaching/learning activities, assessment methods, and content. For the teaching/learning activities and Assessment methods, it is recommended to collect practices that worked within similar contexts and seek inspiration from best methods in literature.

For the content block, educators should define the material that can be taught and the resources that can be used to support the content (e.g. podcasts, recorded talks, scientific papers).

The block for the intended learning outcomes aims to make sense of the student motivation and learning objectives topics. In this theme, educators can turn collected goals into actionable learning outcomes that are described with a level of performance.

Use scenarios of the canvas

The proposed visual tool can be used in different design settings. It is suitable for developing a course, a workshop, an extra-curricular activity, or a training of any format (i.e., in-person, distance, hybrid). Apart from facilitating data collection and synthesis, the canvas can be used as a:

- Tool for communicating user research results.
- Database for future design research.
- Tool to collect feedback in the testing phase.
- Means to have a clear traceability of collected information for further iterations of the solution.

Illustration of use

In this part, we present a guiding illustration of how this tool can be used for designing an introduction to engineering workshop for freshman students in a public institution.

The first step in the context research is to fill out the canvas with information that educators already know and explore what they need to know. Normally, this would start by outlining the explicit knowledge of the research. This is applicable for the institution context category. For that, we

recommend starting the research by collecting data for this category and filling the missing information, as detailed in Figure 5. Ideally, educators would use the database management system of the institution or go through interviews with the resource management department. The research should point out available resources for an extra-curricular activity while taking into account time constraints such as schedules, working hours for faculty and staff, holidays, etc. For the learning objectives block, educators can specify the ABET criteria for student outcomes by focusing on the top in-demand skills. If the goal of the design team is to enhance leadership, social influence, and creativity skills of freshman, for instance, then the focus would be on the following ABET outcomes [25]:

- "Ability to communicate effectively with a range of audiences",
- "Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives".

To conduct the learner context research, educators need to prepare for interviews, and eventually define immersion and observation scenarios. Assuming that from the institution's context research, educators noticed that learning could take place in-person under a specific protocol, then the focus in the learner research would be on understanding students' environment and pain points in this particular situation. For defining the intended learning outcomes, content, assessment methods and teaching activities of the workshop, educators would associate the motivation of the student with the learning objectives of the institution while considering the collected information about both contexts.

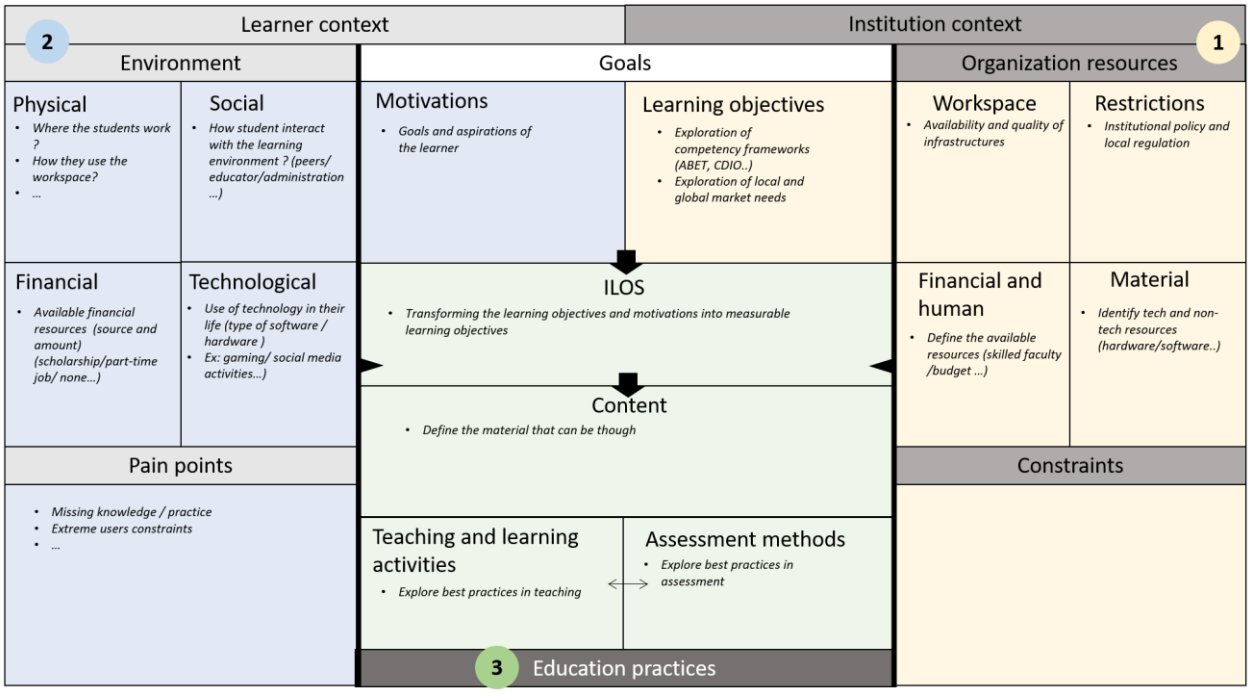

Figure 5: Order for the context research.

Conclusion

The goal of education must be the creation of an adapted learning experience that leads to the development of 21st century skills. Therefore, designing good educational solutions that fulfill the sought-after skills requires an understanding of the learner and institution context along with a knowledge of practices and trends in education. Based on conceptual frameworks for educational design, this work proposed an actionable canvas that guides educators in searching and synthesizing relevant contextual information. The context canvas is dedicated to enhance the effectiveness and accessibility to education design. The prototype of the solution presented here is in early development and needs further testing and refinement based on feedbacks from designers and engineering educators.

References

[1] Liedtka, Jeanne. "Why design thinking works." *Harvard Business Review* 96.5 (2018): 72-79.

[2] Osterwalder, Alexander, et al. *Value proposition design: How to create products and services customers want*. John Wiley & Sons, 2014.

[3] Lattuca, Lisa R., Inger Bergom, and David B. Knight. "Professional development, departmental contexts, and use of instructional strategies." *Journal of Engineering Education* 103.4 (2014): 549-572.

[4] Garreta-Domingo, Muriel, Peter B. Sloep, and Davinia Hernández-Leo. "Human-centred design to empower "teachers as designers". *British Journal of Educational Technology* 49.6 (2018): 1113-1130.

[5] IDEO.org, "The Field guide to Human-centered Design: Design kit". IDEO (2015)

[6] Biggs, John. "Enhancing education through constructive alignment", Higher Education, pp. 347-364, 1996.

[7] Biggs, John. "Aligning teaching for construction learning", Higher Education Academy, 2003.

[8] Astin, Alexander W. "Assessment for excellence: The philosophy and practice of assessment and evaluation in higher education". *Rowman & Littlefield Publishers*, 2012.

[9] Brown, Tim. "Design thinking." *Harvard business review* 86.6 (2008): 84.

[10] S. Doorley et al, "Design Thinking Bootleg", *d.school at Stanford University*, 2018.

[11] Kleinsmann, Maaike, et al. "Communicating actionable user research for human-centered design." *Artificial Intelligence for Engineering Design, Analysis and Manufacturing: AI EDAM* 27.2 (2013): 143.

[12] Fuge, Mark, and Alice Agogino. "Pattern analysis of IDEO's human-centered design methods in developing regions." *Journal of Mechanical Design* 137.7 (2015).

[13] Hanington, Bruce. "Methods in the making: A perspective on the state of human research in design." *Design issues* 19.4 (2003): 9-18.

[14] Hansen, Claus Thorp, and Mogens Myrup Andreasen. "A mapping of design decision-making." *DS 32: Proceedings of DESIGN 2004, the 8th International Design Conference, Dubrovnik, Croatia*. 2004.

[15] Dym, Clive L., et al. "Engineering design thinking, teaching, and learning." *Journal of engineering education* 94.1 (2005): 103-120.

[16] Tonetto, L. M., and P. Tamminen. "Understanding the role of intuition in decision-making when designing for experiences: contributions from cognitive psychology." *Theoretical Issues in Ergonomics Science* 16.6 (2015): 631-642.

[17] Daly, Shanna R., Robin S. Adams, and George M. Bodner. "What does it mean to design? A qualitative investigation of design professionals' experiences." *Journal of Engineering Education* 101.2 (2012): 187-219.

[18] Ling, T., Y. G. Xiao, and P. G. Badke-Schaub. "HOW INTUITION AFFECTS DESIGNERS'DECISION MAKING: AN INTERVIEW STUDY." *DS 77: Proceedings of the DESIGN 2014 13th International Design Conference*. 2014.

[19] Martin, Roger L. "The opposable mind: How successful leaders win through integrative thinking". *Harvard Business Press*, 2009.https://hbr.org/2007/06/how-successful-leaders-think

[20] Murray, Jaclyn K., et al. "Design by taking perspectives: How engineers explore problems." *Journal of Engineering Education* 108.2 (2019): 248-275.

[21] Catalano, George D., and Karen Catalano. "Transformation: From teacher-centered to student-centered engineering education." *Journal of Engineering Education* 88.1 (1999): 59-64.

[22] Laperrouza, Marc, Jacques Lanares, and Emmanuel Sylvestre. "Visualizing constructive alignment in the process of course design." 5Th International Conference On Higher Education Advances (Head'19). No. *CONF. UNIV POLITECNICA VALENCIA*, 2019.

[23] William A Kline, et al. "The Innovation Canvas - A Tool to Develop Integrated Product Designs and Business Models". *2013 ASEE Annual Conference & Exposition, Atlanta, Georgia, 2013, June. ASEE Conferences*, 2013

[24] Ahmad Smaili, Kazem Kazerounian, and Kinda Khalaf. "Design For Culture". *2007 Annual Conference & Exposition, Honolulu, Hawaii, 2007, June. ASEE Conferences*, 2007.

[25] ABET.org. "Criteria for Accrediting Engineering Programs, 2020 – 2021". Retrieved from: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/