DEVELOPMENT OF AN EXTENDED CONSTRUCTIVE ALIGNMENT MODEL FOR REDESIGNING COURSES TO FIT DISRUPTED CONTEXTS

Imane Aboutajedyne
Department of Mechanical Engineering
Faculty of Science and Technology
Sidi Mohammed Ben Abdellah University.
Fez, Morocco
imane.aboutajedyne@usmba.ac.ma

Ahmed Aboutajeddine
Department of Mechanical Engineering
Faculty of Science and Technology
Sidi Mohammed Ben Abdellah University.
Fez, Morocco
ahmed.aboutajeddine@usmba.ac.ma

Yassine Salih Alj
School of Science and Engineering
Al Akhawayn University in Ifrane
Ifrane, Morocco
Y.SalihAlj@aui.ma

***Abstract*— Nowadays engineers are required to solve unprecedented, complex and context-related problems. To address this challenge, many universities have reformed their education systems to more efficient and innovative ones. However, due to the global Covid-19 crisis, universities are challenged to ensure the continuity of education without compromising the attained quality of learning they have invested in. Therefore, adapting engineering education systems to the probable lasting Covid-19 context is of critical importance today. Besides, the existing course-models (suitable for a normal context) cannot be equally efficient when delivered in their original format in the new constrained context. Thus, educational institutions need to envision new structures for their learning; particularly, new delivery patterns to complement traditional physical classrooms. Hence, to ensure continuity of quality education, emphasis should be placed on the consolidation of best practices in learning by taking into account the present disrupted contexts of both students and schools. In this regard, this work proposes an extended constructive alignment vision that integrates context outcomes as a new pillar into the methodology, to which has to be aligned, the intended learning outcomes, the teaching and learning activities and the appropriate assessment methods. The context outcomes, as key parameters of school and student connectivity for instance, are obtained by using a collection of human-centered design exploration tools. Consequently, an instructional design process is proposed based on this vision. Thereby, to illustrate the redesign of courses to fit disrupted contexts, the transformation of an existing course on Product Design for engineering students is documented following the proposed process. Finally, to continue building the future skilled engineering workforce in period of education disruption, the proposed approach is intended to help educators navigate world shifts by adapting their courses to changing contexts without compromising the quality of education.**

Keywords*— *Covid-19, Disrupted context, Engineering education, Human-centered design, Constructive alignment, context outcomes.

I. INTRODUCTION

The present global health crisis is drastically hindering education around world. Indeed, over 90 percent of the world's student population are affected with the closure of schools and universities [1]. Besides, in view of technological and job market disruptions, engineering education is challenged to continue maintaining quality of learning for the attainment of 21st century skills, while assuring sustainable delivery of education in this restricted context. Therefore, education systems are now forced to rethink how to properly prepare the future workforce in a constrained environment. For that, new measures need to be considered for achieving inclusive quality education and ensuring continuity of learning [2]. For instance, access to learning materials, considerations of internet connectivity, the satisfaction of safe social interaction for students, teacher preparedness to deal with the change, and alignment of best teaching and assessment practices with the program learning outcomes, are criteria of primary importance for effective delivery of learning.

In fact, as a result of education reforms in recent years, numerous engineering education systems worldwide introduced new educational practices and novel generations of engineering programs, often adapted to the regional needs and constraints [3]. Courses were designed in a way to help students learn better in physical environments that are supported by school furnishings and concrete learning materials, mostly provided by the institution. Lessons were shaped for a physical social interaction with peers and instructors. However, due to the pandemic restrictions, pre-established course models - suited for a former context - are no longer appropriate for assuring the continuity of learning. On the other hand, during this crisis, the education sector has witnessed new approaches to support the learning continuity in a remote manner. From radio and television educational broadcasts to advanced technological solutions, institutions were able to deliver the learning content to students [4]. However, these solutions may forsake disadvantaged students who do not have access to either connectivity or the necessary digital devices [5]. Moreover, the content offered was not primarily designed for a distance higher education course and was dispensed only to offset the absence of in-person classes [6]. In addition, these solutions have stressed the critical need to foster the commitment and engagement of students to learning and to strengthen their social skills through instructor-students interactions and peer interactions [7].

Hence, despite adopting new approaches in education delivery, the proposed solutions remained ineffective for achieving the sought quality of learning. In this regard, innovative design methods and breakthrough educational practices are needed to create efficient and flexible course models adapted to the present context [15]. More importantly, in short term, existing courses have to be remodeled to comply with the severe consequences of the crisis on the student's environment and the university's abilities.

In light of these new circumstances, this work proposes an extended version of constructive alignment that integrates a new principle dedicated to the context in which education is delivered. The proposed version is elaborated to define and align the context outcomes to the basic three-dimensional approach of Constructive Alignment (CA), composed of the intended learning outcomes, the teaching and learning activities, and the assessment methods. The context outcomes are obtained using exploration tools from the human-centred design (HCD) approach. Consequently, the extended constructive alignment approach is employed to create a context-centred instructional design process based on the

rationale of the Design Thinking process of IDEO -the design company.

The proposed design process aims to enable educators consider the unstated and new elements of the educational context in order to, early-on, define both the feasibility scope and stakeholders needs for the successful creation of appropriate educational solutions. Additionally, the proposed design approach is thought to allow educators prototype, test and iterate their solution prior to formal implementation.

Finally, this work represents a concrete application of the proposed solution for redesigning a course in a graduate mechanical engineering curriculum. The application follows, step-by-step, the guidelines of the context-centred instructional design process and is considered as a testing sequence of the proposed design process for further ameliorations of this work.

Lastly, the paper is structured as follows. In Section 2, the fundaments of Constructive Alignment (CA) are presented and the value of the context in design is highlighted. In Section 3, the proposed vision of an extended Constructive Alignment is presented and a subsequent instructional design process for both outcome-based learning and context-oriented education is explicated. Section 4 is dedicated to the application of the proposed vision for the redesign of an existing course on Product Development, in the mechanical engineering program at our institution.

II. PRELIMINARY

In order to extend Constructive Alignment to a more context-centered approach, the strengths and limitations of the original model are overviewed first. Later, the broad importance of considering contexts when designing is highlighted, and Human Centered Design process - as a method for considering the context - is introduced and explained.

A. Constructive Alignment

Derived from a combination of the constructivist learning theory and the instructional design rationale, the Constructive Alignment approach was created to enable educators to develop an outcome-based approach to education in which the learning objectives are the drivers of the aligned course design [8]. CA involves the three following principles (Fig. 1):

- Definition of the Intended Learning Outcomes (ILOs)
- Description of the Teaching and Learning activities (TLA) required for the realisation of the ILOs.
- Specification of the Assessment Methods (AM) to test whether the student has attained the intended learning outcomes.

As a conceptual framework, the CA model is used for the configuration of the teaching and learning activities (TLA) of a course, and the assessment methods (AM) in accordance with the intended learning outcomes (ILOs) [8]. The ILOs are defined beforehand and indicate the target level of performance that represents the required cognitive level for each learning objective that, in turn, will help specify the teaching and learning activities and assessment methods that best address the achievement and evaluation of the ILOs.

Given the constructivism aspect of the method that defines the learning success in the learner's ability to construct their knowledge through relevant activities undertaken by the student itself [9], the ILOs statement has to contain an action verb that specifies the learning activities the students need to perform to attain the outcome. The SOLO taxonomy, which stands for the Structure of the Observed Learning Outcome, represents the verbs that can be used to indicate the sought levels of understanding in the learning outcome [10]. Literature reveals that constructively aligned teaching produced an enhanced quality of learning outcomes and contributed to student satisfaction [11].

It is true that CA places the learner's educational objectives at the center of the course design approach; however, CA principles only focus on the learning and educational aspect of the student such as his prerequisite knowledge and abilities but do not consider his life-related environment and his circumstances outside the classroom. Moreover, CA does not include the consideration of the educational institution context that may face diverse limitations and constraints. Staff qualifications and limited financial resources, for instance, have a large influence on the teaching and learning quality [12]. Additionally, the approach is still facing implementation issues mostly related to; the institutional teaching policy, the teacher promotion requirements that focus on the research productivity rather than the teaching quality, the teacher's resistance to change to transform from a teacher-centered view for education to the student-centered view [11].

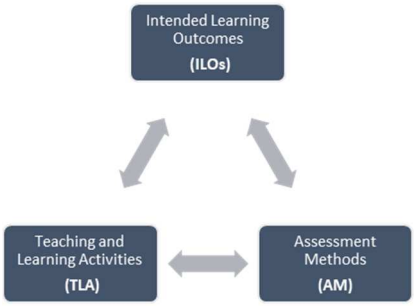

Fig. 1. Constructive alignment principles

B. Context in design

As human needs to evolve and competitiveness becomes accrue in the business market, the need for the design of valuable solutions for customers becomes the target of every designer. A shift was needed from product-oriented design to customer-centric value proposition. To address this challenge, the design research developed various approaches for designing for the customer needs. The customer-centered approach focuses on understanding the customer perspective and embracing his setting in the design process.

This vision has subsequently emerged and has been popularized as the Human-Centered design (HCD) approach. Innovative design companies and leading design schools brought the approach forward and created divers creative tools for each step of the HCD process from problem definition to product creation [13,14]. To define the design problem and perceive the intended challenge outcomes, HCD proposes various ethnographic exploration tools for designers to discover the stated and unexpressed needs through either interacting with the customer to understand his frustrations, or immersing oneself within his context (Table. 1).

TABLE I. HCD EXPLORATION TOOLS

Empathy and observation	Interaction
Immersion	interviews
Peers observing peers	Five whys
Empathy map	Card sort
Guided tour	Extreme/Mainstream Users
Customer Journey	surveys
photojournal	Focus Group

III. THE PROPOSED APPROACH

Considering the relevance of introducing the context of education stakeholders in the instructional design approach, this work proposes a design model that puts forward a context-integrative approach for the design of courses. The first step was to extend the original CA to include a new principle described as the *Context Outcomes (COs).* Afterward, the extended constructive alignment (ECA) is integrated into Human-centred design process to create, thereby, a human-centred instructional design process.

A. Extended constructive alignement

To obtain an effective learning structure, the ECA presents a new configuration for the alignment of learning design principles (Fig. 2); the teaching and learning activities and the assessment methods need to be not only aligned to the ILOs but also associated with the context outcomes. The objective of the COs element is to inform educator about the limitations that may inhibit the accomplishment of the TLA and AM. The COs involves and understanding of the students, educators and university context in which education will be delivered. The statement of the COs will therefore help define the appropriate TLA and AM that, in turn, have to be aligned to the ILOs.

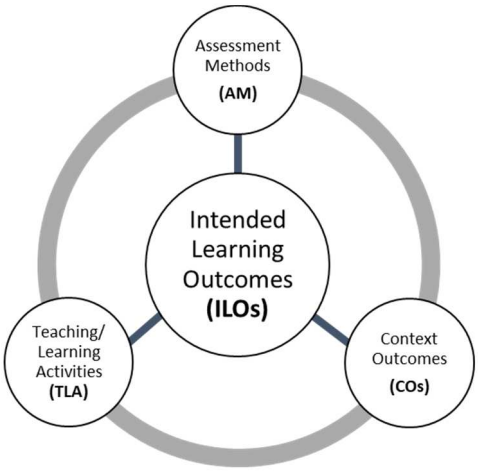

Fig. 2. Extended constructive alignment

B. Human-centered instructional design process

In this work, we leverage on the Human-centered design process of the design company IDEO to develop a context aligned instructional design model. IDEO describes the HCD approach as a creative process for identifying the needs, gathering information, generating potential solutions, refining ideas, and testing solutions [13]. The instructional HCD proposed in this work encompasses the three following phases (Fig. 3):

- Inspiration, which includes two sub-steps: Discover and Interpret. Inspiration enables to well define the problem through an investigation of the customer needs.
- Ideation: supports the generation and experimentation of ideas for the identified needs.
- Implementation: helps to bring most promising ideas to life and plans for their application.

The starting point for course design and development is the statement of the intended student learning outcomes. Educators have to explore competency frameworks to define the ILOs. The ABET student outcomes for instance, are appropriate for the definition of course learning outcomes. Afterwards, in the discover and interpret steps, educators need to use HCD exploration tools to gather critical information on how students are coping with closures and the pandemic, and also define the university and educators constraints and abilities. The next step in the ideation phase is to first; generate teaching and learning activities, and assessment methods that are appropriate or adaptable to the context outcomes and second, propose, test, and select scenarios of aligned learning configurations. The last step of the process requires educators to plan for the implementation of the agreed-upon solution and move to the execution of the course.

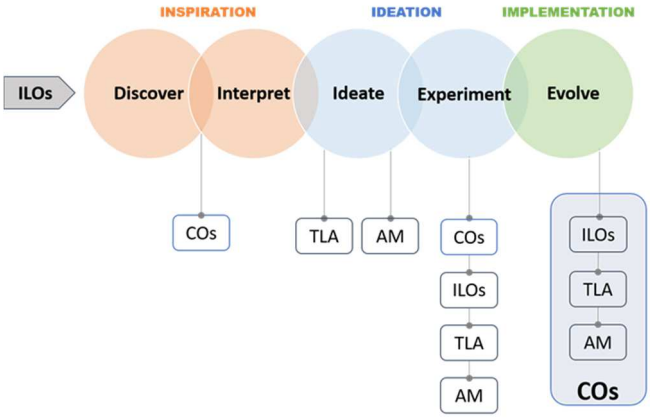

Fig. 3. Proposed Instructional design process

IV. ILLUSTRATION OF USE

With respect to the Covid-19 context, education institutions needed to rapidly respond to the change and adapt their courses and delivery methods to the new circumstances. In order to find solutions that ensure accessibility to all students and take into account the institution limitations including faculty and students constraints, we have applied the proposed human-centered instructional design process to re-design a course on product development in the mechanical engineering program at our institution. 50 students from across the country are registered to this course for the spring term 2021.

In the pre-pandemic period, the learning was fully in-person, the course was organized as a series of lectures along with hands-on projects. Continuous assessment, final exams,

and project evaluation were the main assessment method. Students used the institution facilities and material to work on the projects. 70% of students lived away from their homes. As closure of university and campus was imposed, students could not access the institution facilities. Hence, educators have to provide teaching in a remote mode and develop a solution that works for every student. Moreover, the students' projects should be tailored for the local context needs, and the new solution has to lead to the achievement of the following course objectives:

- Understand the rationale of design tools and use them appropriately.
- Ability to apply creative methodologies to generate new concepts.
- Ability to demonstrate a holistic view and thinking aptitudes of design.
- Ability to apply engineering design to produce solutions that meet specific needs of the local community.
- Ability to identify, formulate, and analyze a problem by applying engineering principles.
- Ability to communicate and work in teams effectively.
- Ability to explore new ideas and new fields of knowledge.
- Demonstrate the ability to adapt to a changing setting.

In the inspiration phase, we identified the context outcomes of stakeholders. For that, we used the extreme /mainstream user research method to define the student context, and internal research with faculty and administration to define the institution's context. The main insights from the research are listed in table 2.

TABLE II. INSIGHTS OF CONTEXT ANALYSIS

Student context	Institution context
• Students living in rural Households do not have internet access at home. • Lack of high-speed internet is some areas. • Students do not often have a personal and quiet space inside the living place. • Unavailability of home office printers and electronic devices such as cameras. • Have the same computer or phone for multiple users. • Limited financial resources.	• Have a limited number of computers • Scarcity of media production equipment • Lack of digital skills of faculty • The Final exam is mandatory regardless of the circumstances.

The context outcomes revealed that providing real-time online learning to all student was not feasible. The learning solutions should be designed for an offline access and be time-flexible. Students have to adapt to their team members constraints and develop their own solutions for communicating and working on projects effectively. Communication with the educator is only possible via phone or emails. Moreover, during the research, the design team inferred that students should also be involved in developing new solutions for education in their context. For that, the student project should be aligned with this goal.

In the ideation phase, multiple solutions were generated and a final concept was selected based on the context outcomes and course objectives. The final concept is as follows;

To get the content of the course, short-recorded videos along with questions to help students engage with the content, need to be sent to students over their communication channels and be uploaded to the professor's website. Besides, for peer-feedback, peer-teaching, and peer-evaluation, students should plan and moderate group-sharing sessions and inform the educator of the output. For the assessment, two individual assignments and two group deliverables are requested throughout the duration of the course, and a final-semester evaluation for group projects is planned. For the projects, students are required to develop cost-effective open laboratories for engineering undergraduate students at the same institution.

For the individual assignments, students have to provide answers to the questions asked in the videos in a creative manner (e.g. storytelling, sketches..). Moreover, they need to report the skills gained through the engineering design process (e.g. teamwork, leadership, empathy…), and how they plan to improve their abilities further. For the group assignments, each group of 3 students have to create concept maps for each chapter with voice recording to explain the map if possible. The assessment of this task is based on the students' ability to list key elements of the content and collaboratively establish connection of knowledge. In addition, they should explain the result of the activities performed in the design process and the used methods for their project. For every assignment, students should be provided with templates and instructions to know what needs to be included in the delivered document.

After completion of the course- in the implementation phase- students are required to provide feedback about the course structure and material, define the constraints, and areas of improvements they perceive. The design team would collect the feedback and include it for further iterations of the course. Besides, a survey can be conducted to define the student satisfaction in the program, and compare it with the satisfaction level for other courses remained unchanged.

V. CONCLUSION

To preserve and enhance the quality of learning in the setting of rapid transformations of the 21st century, educators have to redesign the existing courses to adapt them to the new environments. This need is even substantial in the context of the current Covid-19 crisis as well as for probable future emergencies. Hence, the acknowledgment of the stakeholders' context should be a critical part of the instructional design process. In this vision, this work presents an extended constructive alignment approach that introduces a new principle for the consideration of the context. The constructively context-aligned approach is integrated therefore into the human-centered design process to develop a human-context centered instructional design process for designing appropriate learning solutions, suitable for the contexts of students, educators, schools, and the system environment as a whole. The application of the proposed

process for redesigning a course on product development resulted in the elaboration of a context-adapted engineering course. In perspective, the proposed version of the conceptual model for education design will be refined to include feedback from educators and designers.

REFERENCES

[1] P. Luthra, “Education: An opportunity to reinvent school,” UNESCO, Jun. 23, 2020. https://en.unesco.org/courier/2020-3/opportunity-reinvent-school.

[2] United Nations, "Policy Brief: Education During COVID-19 and Beyond", August 2020. Available : https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/08/sg_policy_brief_covid-19_and_education_august_2020.pdf

[3] Graham, Ruth. "The global state of the art in engineering education." Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA (2018).

[4] Schleicher, Andreas. "The Impact of Covid-19 on education: insights From Education At a Glance 2020", OCDE (2020). Available: https://www.oecd.org/education/the-impact-of-covid-19-on-education-insights-education-at-a-glance-2020.pdf.

[5] UNHCR," supporting continued access to education during covid-19: Emerging Promising Practices, Issue 2" Education section, July 2020.

[6] UNESCO International Institute for Higher Education in Latin America and the Caribbean (IESALC), "COVID-19 and Higher Education: Today and tomorrow", 2020. Retrieved from http://www.iesalc.unesco.org/en/wp-content/uploads/2020/04/COVID-19-EN-090420-2.pdf

[7] UNESCO, UNICEF, the World Bank, and World Food Program, “framework for reopening schools.” 2020. Available: https://unesdoc.unesco.org/ark:/48223/pf0000373348/PDF/373348eng.pdf.multi.

[8] J. Biggs, "Enhancing teaching through constructive alignment", *High Education* 32**,** 347–364 (1996). https://doi.org/10.1007/BF00138871

[9] J. Biggs, "Aligning teaching for construction learning", *Higher Education Academy*, 2003

[10] J. Biggs et K. Collis, "Towards a Model of School-based Curriculum Development and Assessment Using the SOLO Taxonomy", *Australian Journal of Education*, vol. 33, nº 2, pp. 151-163, Aug. 1989, doi: 10.1177/168781408903300205.

[11] J. Biggs, "Constructive Alignment in university teaching", *HERDSA Review of Higher Education*, Vol. 1, pp. 05-22, 2014.

[12] J. Kojmane, & A. Aboutajeddine, (2016). Strengthening engineering design skills of first-year university students under resources constraints. *International Journal of Mechanical Engineering Education*, *44*(2), 148-164.

[13] IDEO, "the field guide to Human-Centered Design", 2015. Available: https://www.ideo.org/

[14] S. Doorley et al, "Design Thinking Bootleg", *d.school at Stanford University,* 2018. Available: https://dschool.stanford.edu/resources/design-thinking-bootleg

[15] I. Aboutajedyne, et al. "A design model for the development of non-traditional educational activities." *2020 6th IEEE Congress on Information Science and Technology (CiSt)*. IEEE, 2021.