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Development of an Innovative Learning Methodology Aiming to Optimise Learners' Spatial Conception in an Online Mechanical CAD Module During COVID-19 Pandemic

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Abstract. The COVID-19 pandemic struck humanity in February 2020. Closures of educational institutions, worldwide, resulted to the creation of emergency remote teaching environments as a substitute to face to face learning. The disruption caused in the academic community has stimulated innovative learning methods within all levels of the educational sector. New parameters affecting knowledge transmission are getting involved while students follow courses apart on a common virtual learning environment. This research is based on a first-semester Mechanical Engineering CAD module in tertiary education. A learning strategy has been applied by reforming the traditional face-to-face leaning mode to a fully remote learning environment. The methods applied have been tested using statistical analysis and have shown to contribute significantly in students' spatial perception in 2-Dimentional Drawings. The outcomes of this research reveal a novel teaching strategy that improved students' academic achievements in CAD during the lockdown. Specific aspects can be considered sustainable on their return back to normality.

Keywords. CAD, Learning strategy, Online Learning, Engineering Education, COVID-19.

1. Introduction

In February 2020, the impact of the COVID-19 pandemic struck the academic community by resulting to the closure of educational institutions around the world. With 94% of the world's student population affected, the pandemic has caused the biggest disruption in education systems in history[1]. Emergency remote teaching environments were created as a substitute for face-to-face learning. During the second quarter of 2020, schools and universities around the world responded to the situation by offering synchronous and asynchronous online learning. Engineering needs, on the other hand, have sparked new learning approaches at all levels of the educational system. Advanced technology tools are introduced into the instructional process [1-6], such as digital platforms and social media channels, serving as the principal mean of knowledge transmission.

[1] United Nations Policy Brief: Education during COVID-19 and beyond AUGUST 2020

The adoption of online-based education in higher education settings around the world offered a unique opportunity to collect electronic data and track students' academic progress, which motivated this study. Specific aspects and learning goals achievement level of the presented modules could be extract out of platform's activity reports, including assessments' results and online surveys.
The novelty of this study consists on the fact that pandemic restrictions have just recently been imposed on educational systems, fully virtual learning environments that provide students' data under these enforced limitations have yet to be evaluated.

1.1. Related work

In order to create a successful learning environment, goals have been determined in each phase of the online module's content flow based on previous studies in the field of Engineering Education. In [7], students' engagement in a learning framework can be differentiated into four behavioral modes during lectures: passive, active, constructive and interactive. Those four stages have been applied in the online module of Mechanical Design with CAD module, under the extenuating learning circumstances of COVID-19 pandemic, when all face-to-face classes have been cancelled and new knowledge sharing solutions should be implemented in a fully remote learning environment. [8]. Previous research has demonstrated a variety of strategies to operationalize the "taking notes" as an index of activity engagement [7]. Asynchronous support can be provided especially in a remote teaching environment, using student friendly modes, including social media channels [9]

In [10], Fuchs made an important argument of using cases in engineering education, aiming to "bring the outside reality into the classroom". Students increase their awareness in real world tasks which motivates them to learn the concepts they need, in order to maximize their performance in engineering disciplines [11]. By introducing tasks, with which engineers will have to deal in their future work, helps developing basic concepts and problem-solving skills, while providing professional experience to the students [12].

2. Module content and description

During the face-to-face learning environment, after attending the ten laboratory lectures, students should be able to represent in 2d views a simple (basic) object referring to a mechanical part, shown in a 3-Dimentional isometric view, by applying the rules of mechanical drawings (orthographic projections hidden edges, visible edges, view placement, top views, side views, sectional views etc.) in a CAD environment. While students are able to represent the visible edges of an object from the isometric given view, their difficulties have been detected on conceiving the bottom views, back views, and sectional views determining the inner form of an object.

One of the basic rules of mechanical drawings is defining an object throughout a minimum number of views, which makes spatial conception an essential aspect of mechanical design. Back, bottom and sectional views are not directly visible in a single isometric view, therefore, have to be interpreted through the hidden edges symbolized by a dashed line. In physical laboratory classrooms, the course flow can be described in the following diagram (figure 1):

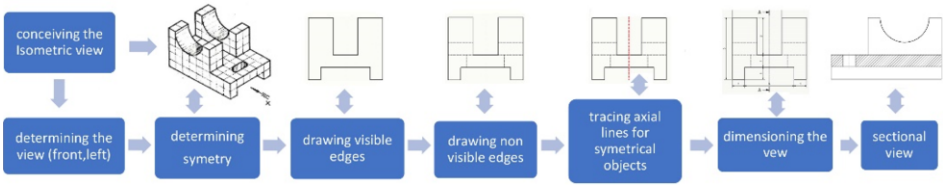

Figure 1. Teaching strategy applied during the face-to-face learning environment

3. The reform of the Mechanical Design CAD module

The reform of the curriculum, due to the COVID-19 imposed distance learning environment, has been based on previous experience of the Emergency Remote Teaching Environment [12] that took place during the spring semester 2019-2020 [13] for the module Mechanical Design CAD II (3-Dimentional modeling module). The outcomes of this research and the student's feedback have been used as guidance for a complete restructure on the Mechanical Design CAD I (2-Dimentional representation module) online module's context.

The goals of this previous experience have been centered on the unexpected intrusion of the COVID-19 pandemic and its social impact to the world's academic population.

The learning strategy has been entirely reformed, while focusing on achieving the learning goals, in a fully remote teaching environment (figure 2). The research has been dwelt on first year students, who had previous experience in online learning, through an ERTE[2] [8] performed on their last high school year, during the first lockdown period in Greece.

The E-course flow is divided in 3 stages:

- The first part consists on passive learning, a lecture during which the theoretical part is presented (figure 3). During this part, learners are engaged in a passive mode [7] where their behavior is limited on listening and paying attention without doing anything else (no need to take notes, a pdf is uploaded in Microsoft Teams files, in the section of each lecture content). Since online synchronous lectures include a real time constructive phase, previous engagement of a passive learning stage should be "pen-free" in order to help students concentrate in the presented topic, relieving them from the anxiety of the note-taking action.
- The second part is followed by a quiz, a self-evaluating activity, aiming to determine the level of understanding of the lecture content, as a cognitive and recall new knowledge stage (figure 3). The Quiz has been created with MS Forms, with inserted images of geometrical shapes corresponding to multiple choice questions. Responders where able to see their results and correct answers immediately after submitting the quiz.
- The third part consists on the first minds on activity: Students have to represent on a 2-Dimentional sketch (scaled freehand drawing) the 3 views of a mechanical part. Methodology is assisted by a video in order to help students apply the new knowledge, after being student passive recipients (figure 3). At

[2] Emergency Remote Teaching Environments

this point, students cannot actively manipulate the video since the instructor holds control while constructively generates the presented methodology by explaining steps and refers to prior knowledge (figure 7). The object is viewed in a 3-Dimentional video of the model while rotated in order to carefully inspect it and fully conceive it [14].

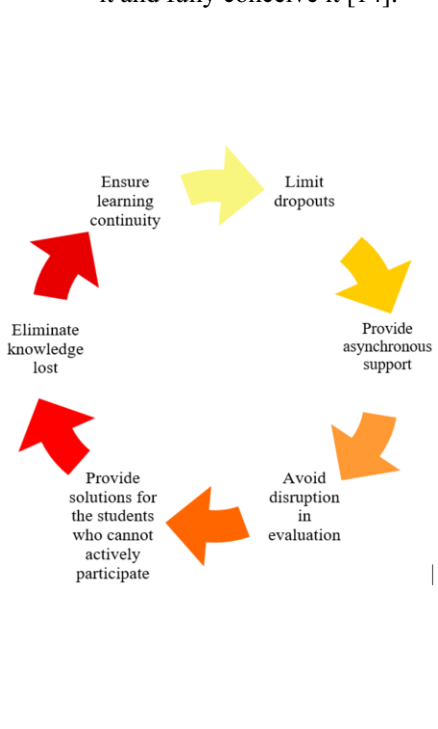

Figure 2. basic goals of the module's reform

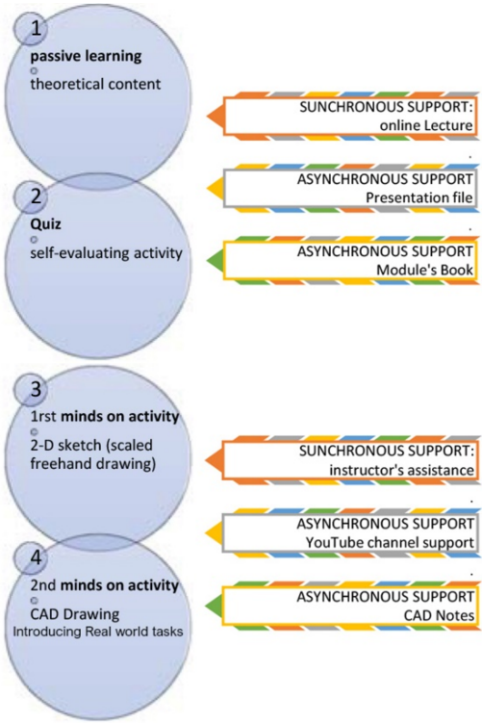

Figure 3. learning's reform strategy

- The fourth part consists on the CAD drawing of the sketched part. Students watch real time instructions via screen sharing, followed by an interactive dialog with their instructor and debating about different ways to achieve the task. Students are also provided with asynchronous instructional support via MCAD I YouTube channel videos. During this phase, a specific task has been assessed to help students on understanding the relation of the tasks assigned through the online CAD I module with real-world tasks, and with their future work in Mechanical Engineering [15] (figure 5).

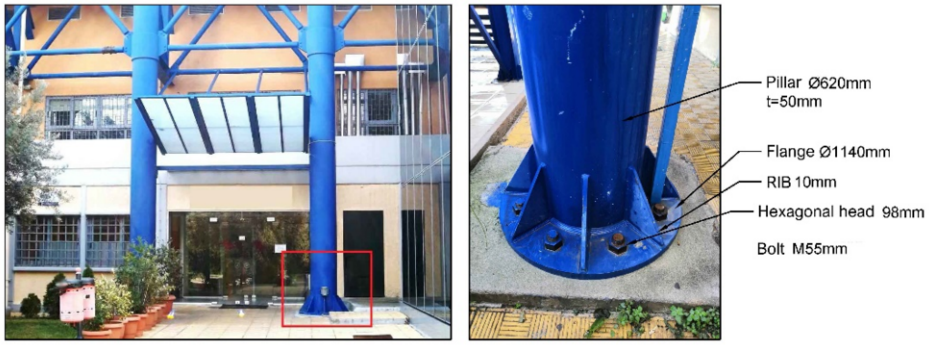

Figure 5. Assignment related to real-world tasks in Mechanical Engineering, uploaded on You Tube

The specific project consists on a CAD drawing of an existing large scale metallic construction and aims to promote the transfer of new knowledge and develop students' co-creating skills. Students should be able to represent in a 2-Dimensional CAD drawing; the existent metallic structure of the library building located in the Ancient Olive campus of the University of West Attica (figure 5). Since most students didn't have the opportunity to visit the campus due to the lockdown, the presentation of the assignment needed to be precise and integrate the most relevant characteristics to the students' future work, which includes most aspects of metallic assemblies like beams, flanges, ribs, bolts, nuts, washers. A video representation of the metallic structure has been uploaded as an added link in the resource option of MS Teams assignment[3] (figure 6), as well as a screen and audio recording of the drawing methodology of basic geometric shapes[4] and AutoCAD commands[5] (polygon, write block, arc, polar array).

Figure 6. Instances from video representation of the 15th assignment on You Tube channel

It should be noted at this point those students who had already developed their special conception had quit sketching. Therefore, they have managed to skip the third part of the online module and did not need to create a scaled freehand drawing in order to proceed on a Computer Aided Design.

All activities where announced, uploaded and graded on MS Teams platform to avoid disruption with several LMS platforms.

[3] https://youtu.be/RWY5EuLB9nQ
[4] https://youtu.be/HT-oJB2JZ9k
[5] Autodesk Autocad 2017 Educational Version

4. Developing students' spatial conception

One of the most critical challenges of this research has been to apply technology features and empirical techniques that could favorize the development of students' spatial perception. The reform strategy induced the surface planes as an exploded view of the given object. Each isometric view has been analyzed in surface planes parallel to one another, perpendicular or even not related to each other. The surface planes where tangent to each edge set, determining a single view. The methodology resulted on helping students conceiving the representation of continuous line segments for visible edges, as well as the tracing of dashed line segments for the non-visible edges, belonging to parallel back planes, while passing from isometric views to 2-Dimentional Drawings. When sectional views have been announced in the virtual classroom, the presence of the cutting plane determining the point on the plane where the sectional view should be drawn, has been highlighted in the isometric view, instead of the typical chain line with thick ends and two arrows in the direction of the view. Each object that has been assessed as task has been previously modeled in Autodesk Inventor 2020[6] in order to be presented in a photoreal view. In the reformed virtual laboratory classrooms, the course flow can be described in the following diagram:

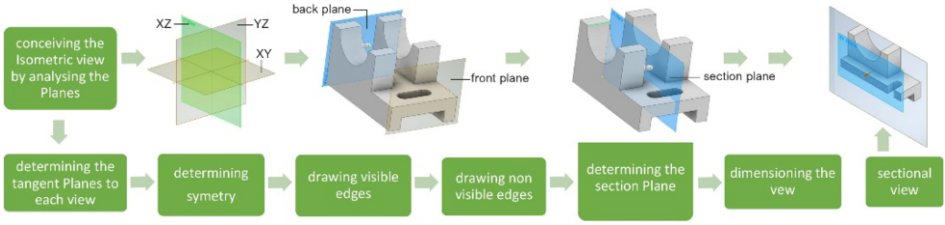

Figure 7. Teaching strategy applied during the virtual learning environment

5. Evaluation of the learning strategy

The online reformed module has been applied to 216 (N=216) students which were divided in 11 online platform teams, assisted by a group of 5 instructors in MS Teams. 190 (n=190) students replied to the surveys out of which 165 where first semester students. Out of the 190 participants, 88% where male and 12% female students.

A univariate analysis has been performed throughout a survey containing 101 questions (variables). Variables that have proven to have a significant relation with the students' final grade in the specific module (Table 1) have been filtered out through a correlation analysis performed in SPSSv2020 using data mined from four sources:

- *1st online survey conducted during the 1rst online lecture:*

The questions provided information about student's previous educational information (i.e. university entrance exams grades in four courses)

- *2nd online questionnaire conducted during the ninth (out of ten) online lecture,*

An online questionnaire including various constructs of the learning strategy has been shared to the students during the eighth out of nine lectures of the academic semester. Constructs' categories included variables indicating the students' emotional

[6] Autodesk Inventor Professional 2020 Educational Version.

state during the lockdown, insecurity, social distancing, evaluation factors in a Likert scale, spatial conception and module content convenient to real world tasks in mechanical engineering.

- *General characteristics of the students, the class croups and the instructors*

The above include gender, age, high school type, class time (morning or afternoon class) number of instructors, instructors id.

- Insights from MS Teams Platform, assignment Grades, Final's exam grade.

6. Qualitative Analysis

The learning strategy has been tested and proved to have a general acceptance from the population that participated.

High ratings have been shown in specific aspects as overall evaluation of the learning strategy, organization, enjoyability of the online module, preference to other laboratory and theoretical courses. The new introduced features aiming to help students improve their special conception have been positively received and highly evaluated by the majority of participants. The sustainability of the learning strategy has been evaluated as well and significant percentages have been localized in the way weekly tasks are assessed 62% (via MS Teams platform), parallel asynchronous support from the MCAD I UNIWA YouTube channel 66.8% and 85% of the students rated the videos between 4-5. Full time lecture recording has not been widely suggested, as the percentage is limited in 45%. Parallel online transmission of each 3hour lecture has been suggested by 51% of the students, which implies that students prefer short videos describing the solving methodology than 3-hour lecture recordings (figure 8).

Table 1: Significant variables (survey questions) corelated to student's positive evaluation

	Significant variables (survey)	Evaluation /5	Evaluation range 4-5
1	Enjoyable vs other Labs	4.33	89%
2	CAD I helped familiarising to MS Teams	4.16	78%
3	CAD I vs other Modules	4.27	83%
4	Confident for the finals CAD I	3.47	53%
5	Confident for the finals all modules	3.12	31%
6	Organisation	4.25	84%
7	Theory contributes on tasks	3.59	55%
8	Planes well-conceived	4.16	81%
9	Importance of section plane	4.47	90%
10	Quality of videos	4.27	85%
11	Clearness of videos	4.17	84%
12	Pleasant experience	4.38	90%
13	Interactivity	3.60	61%
14	Questions resolved	4.32	83%
15	Assignments related to future tasks	3.84	62%
16	15th assignment video	4.01	76%

17	15th assignment related to real world tasks	4.08	77%
18	Evaluation vs other labs	4.19	82%
19	Overall evaluation	4.21	85%

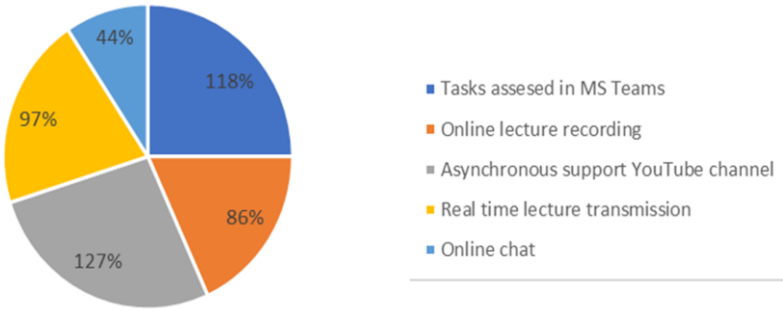

Figure 8. Percentage of preference in Sustainable learning modes and support

7. Conclusions and Future work

Learning materials, online accessibility, student involvement, and communication have always been essential to the e-learning philosophy [16]. During the transition from face-to-face to the COVID-19 emerging learning environments, most University online modules' lectures and Laboratories in the University of West Attica have been using simultaneously MS Teams (Communication Platform) for the synchronous lectures and Moodle or E-class (Learning Management Systems) for asynchronous support. The last included tasks' assessment, gradings, modules' notes and final semester exams. The procedure previously mentioned aimed to facilitate the transition mostly for educators who have been using LMSs before the pandemic, due to the lack of time for preparing the material but also for getting more familiarized to MS Teams. During the first period of the pandemic, the use of both platforms has caused confusion in most students with inferior computer skills.

One of the most important outcomes of this study is that using a single online platform for transmitting synchronous lectures and at the same time uploading tasks' assessment, module notes, and grading and asynchronous support facilitates task's organization in both students and instructors. In this case where asynchronous support has been provided by social media channels (in this case YouTube MCAD I UNIWA channel), integrating assignments and resources links uploaded on social media channels has contributed on organizing functionalities for educators and at the same time provided direct access and control to students, for managing their homework schedule.

By determining educational patterns and learning modes that have been issued while transforming an existent face-to-face laboratory course to a fully remote teaching environment, the question is whether some of those learning modes can be applied in the future, on the return to real classroom environment, by the means of a synchronous or asynchronous support, or even as a point of reference of each lecture content.

Future work consists of applying the single platform educational mode to first-semester students who will be attending the same module during the academic year 2021-2022, in a similar, blended or virtual learning environment in order to determine the sustainability of the methodology suggested by this study, in future learning environments.

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