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TOWARD TO AN EDUCATION 4.0 – POWERED TEACHING MODEL FOR HIGHER EDUCATION

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Hacia una Educación 4.0 - Modelo de Enseñanza Potenciada para la Educación Superior

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ABSTRACT

In this work, we investigate a teaching model for higher education that employs Education 4.0-based learning practices to engage and to increase the level of knowledge and abilities of involved students. Our aim is to select the most relevant learning practices taking into account student profiles (i.e. which competencies must be developed in these students to make a deeper learning) and teacher profiles (i.e. which competencies the teachers need to have to properly conduct the application of these practices). We address agile methodologies as a base to apply such practices for both online and offline teaching environments. We also incorporate in our approach some extracted techniques from scientific literature such as the BLOOM taxonomy (utilized in our assessment process) and the ADDIE model (associated with components, premises, constraints, rules, and indicators). We also discuss how this model must be utilized to improve the experience of both students and teachers.

Keywords: Constructivism, Offline/Online Teaching, BLOOM Taxonomy.

1 INTRODUCTION

The constructivism theory is one of the most significant pedagogical approaches for applying into active learning-based future classrooms (Niemi, 2002). The main goal of this learning theory is to enable students to construct their own knowledge, ideas and concepts through an environment that stimulates them to perform teaching learning practices. Likewise, students are an active part in the process of learning by doing (e.g., building artifacts or objects), being encouraged to perform various actions to acquire a deeper knowledge about the topic in question. This theory enables students perform self-evaluation in their process of building knowledge thus creating an experience and competence about the subject. These competencies are extracted from the P21 framework (Salas-Pilco, 2013), an initiative to indicate the most valued competencies in the XXI century. Competencies-based approach in education is one of the most disruptive approaches to prepare students to face the challenges of this century (Makulova et al., 2015).

However, some drawbacks are considered large challenges to establish an acceptable level of performance. The first drawback is related to lack of studies in literature about competencies and pedagogical practices since these practices are based on learning theories that could better develop the necessary competencies for students. There is a real necessity of creating models to associate which learning theories and teaching learning practices may be effective to implement such competencies and to correspond to the challenges of the XXI century. The second drawback is related to lack of studies in literature about how we could associate the choice of these competencies to student profile. Personalizing is essential to make students more engaged and connected with the topic to be taught. Therefore, understanding which competencies each student has and which competencies must be developed by them is relevant to recommend the best pedagogical practices that enable such students to achieve higher levels of knowledge. The third drawback is related to lack of studies in literature about how we could develop teacher-related competencies to provide a high level of mentoring and management in the execution of pedagogical practices performed by students (Auerbach et al., 2018). The application of these practices must be dynamic and self-paced, which requires knowledge and skills of teachers (e.g., usage of educational technologies, agile methodology, project management skills, and so on) to transform offline and online teaching experience more valuable.

In this work, we propose an Education 4.0-centered teaching model that employs constructivism tasks to increase knowledge and engagement level of involved students. We consider student profiles to recommend the best learning practices. This model incorporates constructivism-related pedagogical practices to create a personalized teaching plan that could be executed into agile methodologies such as SCRUM, XP, Crystal, PRINCE2, among others (Vogelzang et al., 2020). We also incorporate well-known techniques in our approach such as BLOOM taxonomy for assessing the knowledge level of our students and the ADDIE model for instructional design. We perform a validation with disciplines of a given higher education course to acquire some insights and to discuss application benefits of this method in offline/online educational environments. The structure of this work is described as follows. Section 2 presents some background about the types of existing education. Section 3 discusses the model and the mode of operation of the proposed approach in this work. Section 4 presents some results of the developed case study in this work. Section 5 discusses the obtained results in the application of this teaching model in higher education. Section 6 presents the final considerations of this article.

2 BACKGROUND

In the last decade, various educational players have addressed efforts to improve school education by moving from a massive education based on teacher instruction to a more personalized and autonomous education with student-centered strategies (Wiggins et al., 2017). Throughout human history, there have been countless ways and means of transmitting knowledge. In the case of the Western, they can be summarized into three models of education: Education 1.0, 2.0 and 3.0 (Gerstein, 2014; Songkram et al., 2019).

Education 1.0 (Gerstein, 2014) considers a teaching composed by small groups or even a single student. Likewise, the teacher assumes the role of a mentor by transferring knowledge and techniques for such students. This kind of education benefited only people with high purchasing power and persisted until the middle of the modern era. After this period, the Industrial Revolution (started on 18h century) required a more democratic education, caused by the large increase in production demands and job requirements. At this moment, the teacher starts teaching classes with dozens of students simultaneously. Education 2.0 (Gerstein, 2014; Tirziu and Vrabie, 2015) represents the mechanization of disseminating knowledge to increase the accessibility of learning. Education 3.0 (Watson et al., 2015; García-Pérez et al., 2016) and Education 4.0 (Hussin, 2018; Ciolacu et al., 2017) are recent paradigms in education due mainly to the appearance of globalization and the advent of the Internet. While Education 4.0 deals with the massive use of emerging technologies such as artificial intelligence, robotics, immersive reality, big data, Internet of things, among others, Education 3.0 employs strategies known as active learning, since teachers become mediators in this teaching learning process and students become the protagonist of their learning.

The authors in Keats and Schmidt (2007) and Lengel (2013) have defined six pillars for the active learning: (i) Students are encouraged to be creative and curious; (ii) Teachers and students produce together; (iii) Students must employ digital tools in their activities; (iv) Students work on real problems and can bring returns to society; (v) Students learn how to tell stories and convey their ideas; and (vi) Students develop self-directed research, which aims to stimulate their protagonism and intellectual autonomy. Within this perspective, there is an environment based on the individualities of each student, while there is an incentive for collective production. Compared to the 1.0 and 2.0 models, a horizontalization of knowledge is also perceived in both Education 3.0 and 4.0.

There are several ways to work on active learning (Freeman et al., 2014). For example, you can employ constructivism-based tasks that create classes based on arts, when a teacher encourages his students to create music or plays on a given topic. We can also transfer previous knowledge about a situation for other contexts by utilizing a mix of competencies such as collaboration, communication, problem solving, or critical thinking. Cooperation can also be worked on when other entities are involved to solve problems. The use of information and communication technologies (ICT) enables students to learn at their own pace. Scientific or non-scientific research can be used to stimulate further study on a given topic. Discussion activities such as panels, forums or simulations can be applied to discuss topics or create groups to analyze content. Projects can be developed in classrooms to stimulate the creativity of students to solve problems. Therefore, the application of constructivism-based methods is highly recommended to provide a good experience into active learning by working on various student skills and creating an experience capable of better retaining knowledge on a topic or solving problems.

3 METHOD

This work proposes a method that considers student profile-related information to increase the accuracy of the teaching-learning process into universities and higher education institutions. This model enables students to learn by doing activities that increment their competencies related to a given content. We incorporate constructivist tasks to apply such practices in both online and offline teaching environments. We also incorporate in our model some well-known techniques such as the BLOOM taxonomy (utilized in our assessment process) and the ADDIE model (associated with components, premises, constraints, rules, and indicators).

3.1 Components

3.1.1 Constructivism Approach

Our model incorporates the PBL method (problem-based learning) as being our core constructivist method. PBL distinguishes behaviorism-related pedagogical methods since it goes against the traditional education system in which the teacher is the only holder of knowledge and the students are only there for reading, copying, and memorizing. In PBL, the student becomes the center of teaching, and the teacher becomes a tutor who guides students on the path to knowledge by identifying its importance in society, and completely changing the interpersonal relationship between teachers and students. In the traditional teaching method, the classroom is structured as a hierarchical pyramid, in which the teacher is at the top and all other students are equally below the teacher; Already in PBL, the structure of the room is more like a road where the teacher is just ahead and guides students to walk on this road.

PBL begins with the creation of a problematic context as the context must be easy to identify the subject of the object of study to instigate the student to learn. After this part, students are divided into groups to identify the information that is needed to solve the problem. Soon after, the students must find the solution to the problem, with all these steps being the teacher acting as a tutor for the students. In the final part, students prepare a synthesis based on the results obtained by the group to present them for evaluation by the teacher. One of the main points of PBL is to allow different approaches to the same problem, mainly benefiting students with difficulty in the addressed subject. This practice facilitates learning and creates an environment that enables a personalized study plan for each student.

3.1.2 ADDIE Model

In this work, we incorporate the ADDIE model defined in Nichols Hess and Greer (2016). as our instructional design, composed by the following stages: (i) Analysis, which encompasses a list of objectives of the target course; (ii) Design, which encompasses a list of premises, constraints, and rules; (iii) Develop, which encompasses a list of key performance indicators (KPI) and essential backlogs to run the agile structure (e.g., constructivism task, and topics backlogs); (iv) Implement, which encompasses the student backlog; and (v) Evaluate. which encompasses assessment techniques and teacher backlog.

The item (i) defines which will be the objectives identified in our model (e.g., employing team activities, individual activities, or guided studies, choosing specific competencies to attend teaching goals). Here the teacher can also define how many cycles will be necessary to attend to its teaching goals. The item (ii) defines what must be essential to start the operation of the proposed model in this work. For example, the premises could indicate which books must be adopted as a reference for studies, which is the teacher role (mentoring, consultant, manager), which is the threshold value of student engagement to continue the application of the teaching method, and so on. The constraints could indicate which tasks must be required and which tasks must be optional in the application of the proposed model, or the definition of how the cumulative and formative assessments would be. The rules could indicate how many tasks must be allocated by each cycle, or how each team must be organized, among others. The item (iii) defines which KPIs must be employed to evaluate the performance of our model. For example, some KPIs could be included such as number of developed artifacts, engagement level on tasks, student satisfaction level, overall student average, among others. Also, a backlog of tasks must be defined to be employed along the execution of the defined cycles and a backlog of the learning modules or topics must be defined to associate to the cycles.

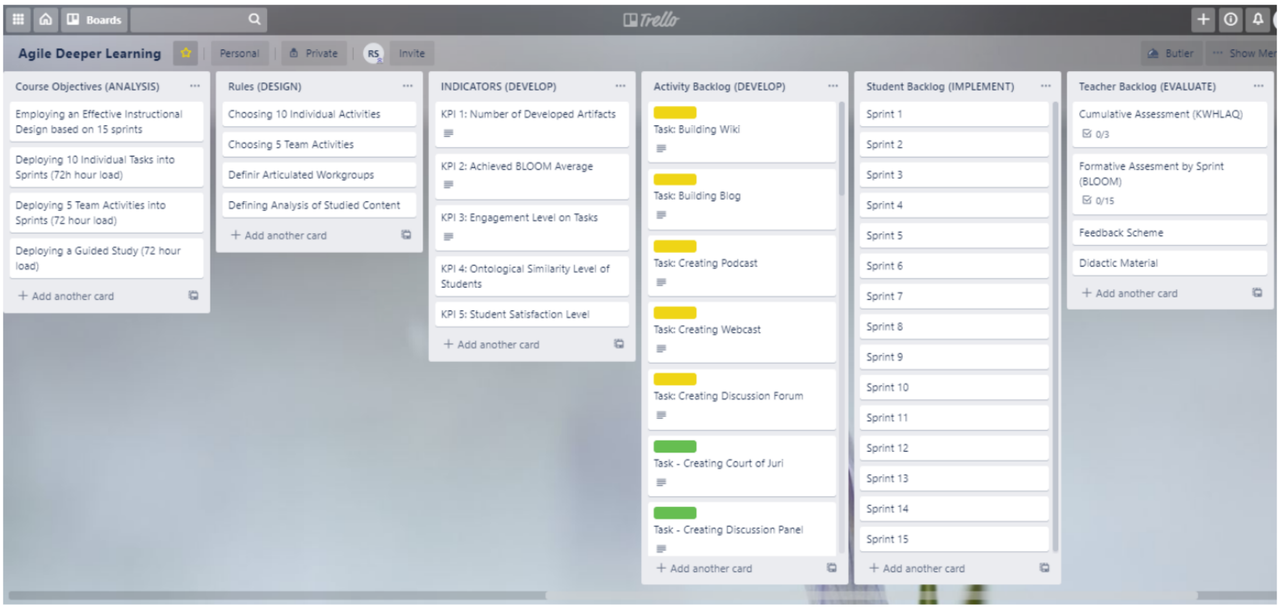

Figure 1: ADDIE Model

The item (iv) defines the student backlog by organizing cycles with the associated activities, the objectives, rules, constraints, and premises to be considered to successfully perform the learning. Each task associated to a given cycle must comprise the requirements of learning given in the Analysis, Design, and Develop stages of the instructional design. The item (v) defines which techniques are employed to perform cumulative and formative assessments.

3.1.3 BLOOM Taxonomy

We utilize the BLOOM taxonomy to measure the level of understanding that a student must have about a given learning module (Thompson et al., 2008). Our formative and cumulative assessment must identify in each student the following capacities: (i) describing, relating, telling, and finding a target topic (i.e. remembering); (ii) discussing, explaining, and predicting about the evaluated theme (i.e. understanding); (iii) using, illustrating, completing, solving problems related to the target subject (i.e. applying); (iv) identifying, comparing, explaining, and categorizing the topics of a given learning module (i.e. analyzing); (v) deciding, prioritizing, rating, and justifying aspects of a given topic (i.e., evaluating); and (vi) creating, imagining, designing, and planning ideas proceeding from the target subject (i.e. creating).

3.1.4 Education 4.0-Centered Technologies

The literacy of ICTs is essential to the success of our approach. Project management-related tools are essential to manage our approach. We can consider iterations as a project articulated between students to accomplish a certain mission. For example, Trello is one of these management tools that provide a more robust control of execution of these tasks in classrooms (illustrated in Fig.1). Tools such as Google classroom enable better organization of artifacts created by students, their assessments, and other kinds of control into classrooms. Authoring tools also are essential since each learning task claims an artifact created by students into some authoring tool such as Google Docs, Sheets, Draw, Slides, Forms, etc. Communication tools also have their space since the sharing of projects, or the collaboration is one of the most important interpersonal competencies and must be provided by communication tools.

3.2 Operation

Suppose that a teacher wants to use the proposed model in this paper in his classes. Your class is composed of students with different backgrounds. It should have the following predefined elements:

- which learning goals must be achieved;
- which premises, constraints, and rules must be formulated to properly conduct the rhythm of his classes;
- which key performance indicators must be defined to evaluate the performance of his classes;
- and which backlogs must be organized to run along sprints.

Initially, a teacher should apply a survey for the class by asking questions that help him to identify the level of skills of all the class (both individual and collective skills). A dataset containing historical class data can also be used to create a snapshot of this profile. With this information, a teacher must select which constructivism activities must be used during the execution of its classes (extracted from task backlog). Then, a teacher must organize the structure of its classes into cycles. This structure should consider the rules, the premises, the learning goals and the constraints presented previously, and the duration of these cycles should be according to a previous analysis of the content to be taught. For example, we could relate each cycle with iterations deriving from agile methodologies. Figure 2 illustrates this association of cycles with the SCRUM agile methodology.

Note that the sequence of topics does not increase consecutively, since the difficulties encountered by students will be able to rewind cycles and create dynamism in the sequence of learning of topics. Once this structure is defined, a table must be constructed for each teaching plan developed. For example, Table 1 enumerates the activities and cycles for each defined task type (i.e. collaborative, individual, and guided).

Table 1.

Example of a Teaching Plan for Collaborative StudyTask

Task ID	Description	Cycle/Sprint	Constraints
01	Creating Wiki	[1, 11]	Optional
02	Creating Blog	[6, 7, 12]	Optional
05	Creating Discussion Forum	[3, 13]	Optional
06	Creating Short Events	[2]	Optional
24	Creating Role Play	[4, 15]	Optional
25	Preparing Storytelling	[10]	Optional
26	Performing Brainstorming	[9]	Optional
30	Creating Inventories	[5, 14]	Optional
31	Creating Short Projects	[8]	Optional

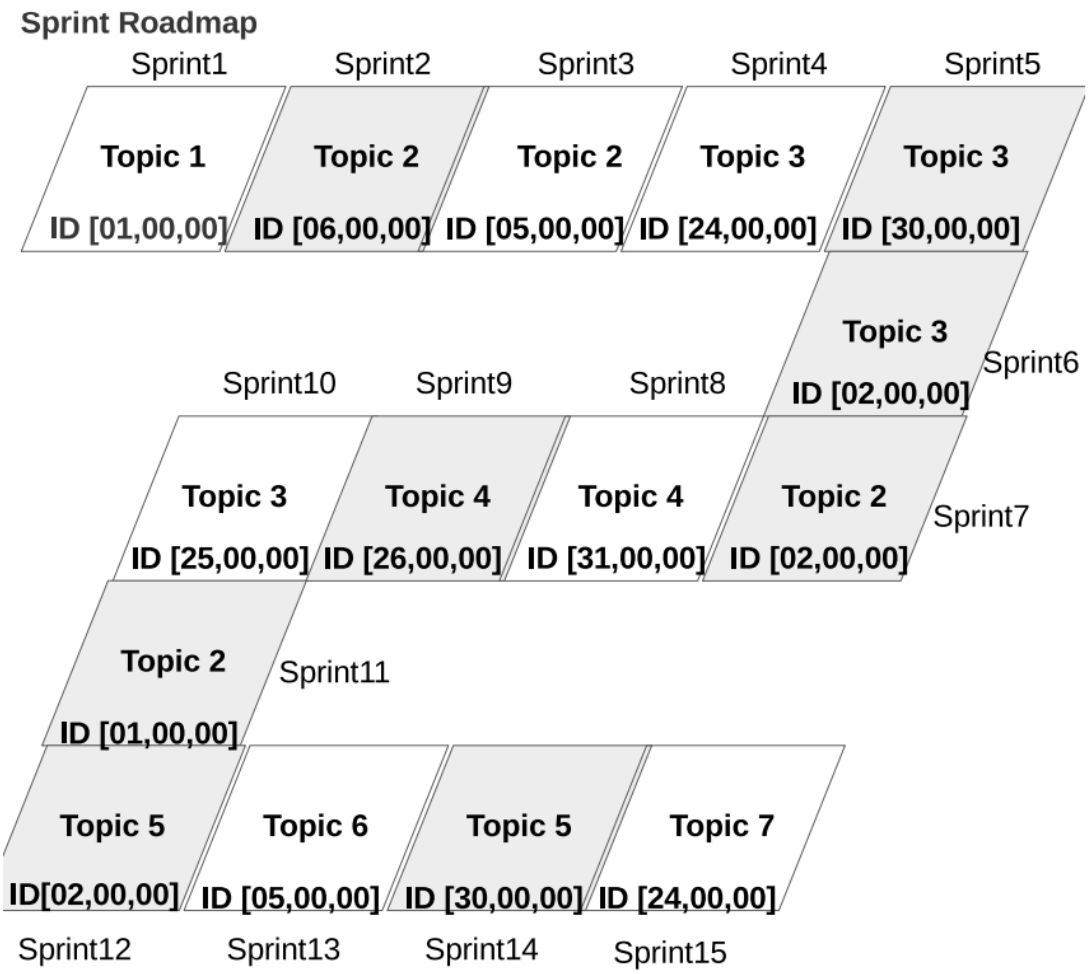

Figure 2: Using Cycles as SCRUM Sprints for Allocation of Constructivism Tasks

To perform an accurate management of these activities, the teacher must use educational technologies that allow control and to monitor the progress of activities. Figure 1 illustrates an example of how this management and monitoring can be done through educational technology. In this case, cards in Trello organize the activities or resources to be considered during monitoring.

4 RESULTS

The proposed model has been applied successfully into 4 disciplines of a Computer Science course in the Computing Institute at the Federal University of Alagoas, in Brazil. This experiment was conducted in 2019/2020 at the disciplines of: (i) Special Topics in Computing **(STC)**; (ii) Natural Computing Project **(NCP)**; (iii) Computer Networks **(CN)**; and (iv) Project Management **(PM)**. All these disciplines are composed of 60 workloads, with 4 months of duration, as presented in Table 2.

In STC, a round of lectures was conducted during the first 2 months of this discipline. The included themes were current and emerging themes such as smart cities, internet of intelligent things (IoIT), Internet of things (IoT) in education, natural computing, home automation, and vehicular networks. The remaining 2 months were divided into 8 iteration cycles: 4 cycles to prepare the students to develop a business technological proposal related to the aforementioned themes; and 4 remaining cycles to create and to present a business plan about the selected technology theme.

Table 2.

Parameters of our performed case study

Item	**Data**
Period	2019 / 2020
Disciplines	(i) Special Topics in Computing; (ii) Natural Computing Project; (iii) Computer Networks; and (iv) Project Management.
Developed Topics	Software project; Academic events; Protocols; Algorithms; Business Plans
Workload	60h
Months	4

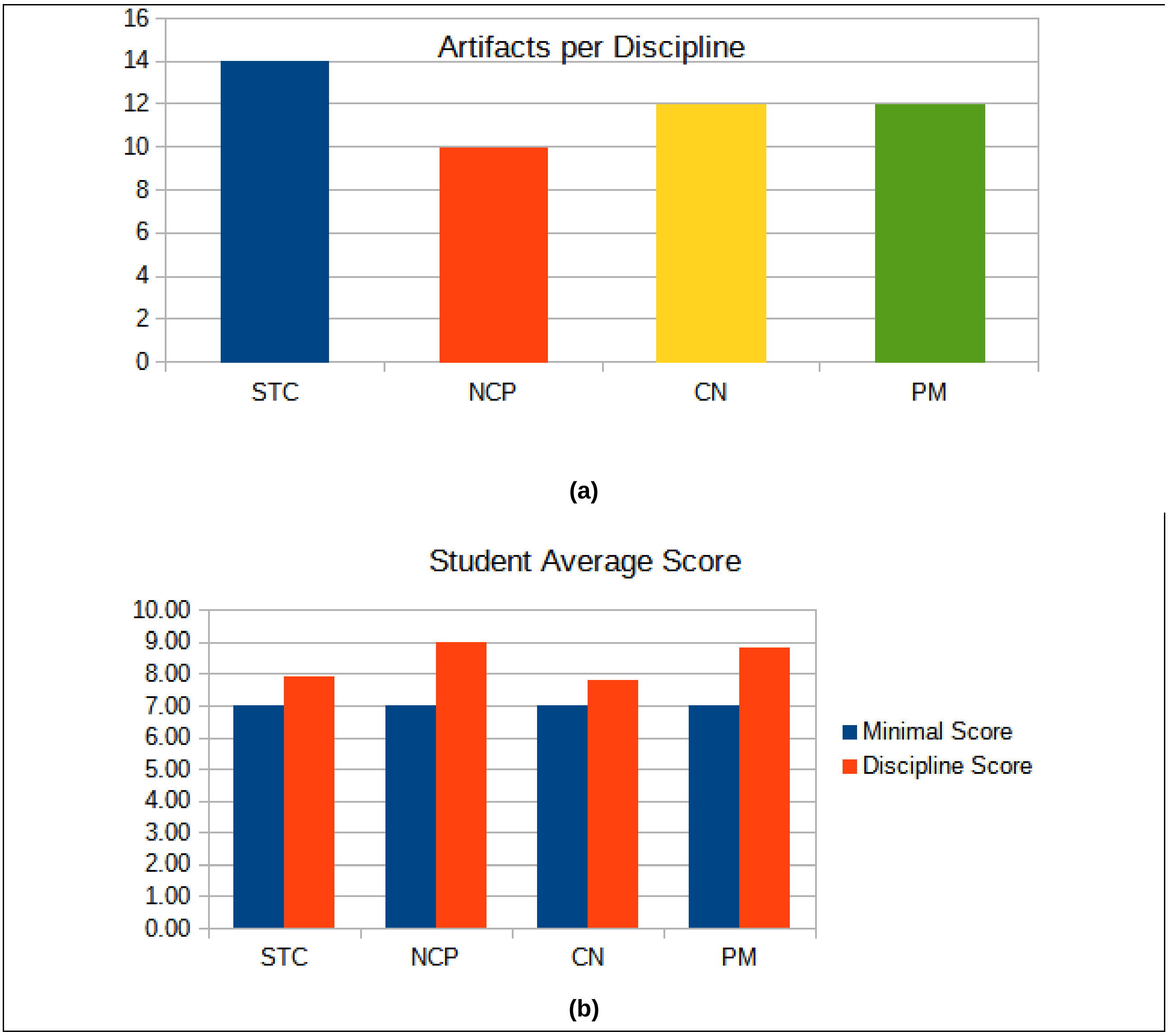

Figure 3: Case Study Results: (a) Produced Artifacts per Discipline; (b) Student performance Average score.

In NCP, a round of lectures was conducted during the first 3 weeks of this discipline. The big picture of natural computing was presented, and its algorithms were explained (i.e., particle swarm, cellular automata, fractals, evolutionary computing, neural computing, and immuno-artificial algorithms). The rest of the discipline was divided into 12 cycles for development of a business plan and the implementation of a natural algorithm chosen by the teams.

In CN, a round of lectures was conducted during the first two months of this discipline. All the content proceeding from the higher layer of the TCP/IP was taught (i.e. application, transport, and network layers). The remaining 2 months were divided into 8 cycles to develop a project about how to improve the existing protocols in the higher layer of the TCP/IP. Basically, each team should investigate a manner of improving these existing protocols or creating a novel protocol written in the RFC standard.

In PM, a round of lectures was conducted along the first 2 months about the current methodologies for project management (PMBoK, PRINCE2). The idea was to teach the involved students how to create an effective project plan by utilizing such methodologies. The remaining 2 months were divided into 8 cycles to organize and to perform an academic event called TechDay, which occurred in a local partner university.

Figure 3 presents the outcomes of this work. In Figure 3 (a), each investigated discipline obtains a high number of produced artifacts due to application of constructivist tasks. Note that all the aforementioned disciplines are capable of generating a production that stimulates several skills in our students such as creativity, critical thinking, communication, collaboration, among others. Figure 3 (b) presents the overall score of each involved discipline. We compare the obtained outcomes with the minimal score necessary to be approved in our undergraduate program. Note that all the disciplines get to obtain this minimal score through the application of our constructivism-based teaching model.

5 DISCUSSION

The usage of our model in the aforementioned disciplines was essential to increase the performance of the involved students about the acquisition of knowledge and the improvement of skills such as collaboration, communication, critical thinking, and problem solving. We would like to highlight the main benefits observed in the application of this model at the higher education:

- Assessment Process: As illustrated in Figure 3 (b), We identify a higher performance than 70% in relation to the grade overall average in all the aforementioned disciplines (i.e. special Topics in Computing was presented an average of 79.3%; Natural Computing Project was presented an average of 90.0%; Computer Networks was presented an average of 78.0%; and Project Management was presented an average of 88.5%). This fact could indicate an acceptable rate of knowledge acquisition by employing constructivism practices.
- Freedom in choosing tasks: Each student is free to choose those tasks that fit well in their purposes. In each novel cycle, a quick meeting is made between students and the teacher to define which will be the next steps. This agile dynamic is crucial to establish adaptations in the student projects and to enable a better exposition about target topics.
- Massive usage of technologies: students have utilized various technologies to perform their allocated tasks such as Trello, Quire, GitHub, RFC Editor, Evernote, programming languages, among others. Consequently, novel skills are acquired by the usage of these tools, and it increases the relevance of using competencies-based approaches to achieve a deeper learning.
- Creation of Artifacts: As illustrated in Figure 3 (a), several artifacts are developed along the discipline lifecycle. For example, software code is developed to run natural computing algorithms in the discipline “natural computing project’ or project plans are created to drive the execution of the academic event in the discipline “project management”. Also, business plans and draft canvas are created in the discipline of special topics in computing and RFC standards are developed in the discipline of computer networks. These artifacts are an outcome of the basic premise of constructionism (a theory derived from constructivism that learns by building artifacts), thus serving as assets for future classes.
- Competencies: All the allocated tasks seek to stimulate the creation of ideas and to improve the creative thinking of students. Therefore, our model has enabled students and teachers to reinforce their competencies and acquire novel competencies for the learning of a given

subject. This approach created a more engaging dynamic and collaboration between students and teachers and critical thinking to solve complex problems.

6 CONCLUDING REMARKS

This work has proposed a teaching-learning method that utilizes constructivist practices to enable students to create content and artifacts that increment their competencies related to a given content. Our method has encompassed a myriad of Information Technologies and Communication-related tools as well as has considered PBL as a core pedagogical practice. Furthermore, our model has incorporated other well-known methodologies such as ADDIE model and BLOOM taxonomy to perform constructivism practices into classrooms. This method was applied into 4 disciplines from a computer science course at a Brazilian university to capture significant evidence about its effectiveness. The results of this application demonstrated the ability of the method to engage and better to prepare skills and student competencies given a set of objects of study.

As a future work, we intend to apply this method in larger and different classes of the computer science course, in Portugal and other countries to have reliable data on its effectiveness. In addition, it is intended to demonstrate the association of other theories such as cognitivism and connectivism to improve the application of practices and become a more personalized teaching. For such, we will intend to extend this model to incorporate agile techniques and modern education theories.

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