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A MODEL FOR PUTTING CONNECTIVISM INTO PRACTICE IN A CLASSROOM ENVIRONMENT

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Dissertation

presented as partial requirement for obtaining the Double Master's Degree Program in Information Systems Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
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A MODEL FOR PUTTING CONNECTIVISM INTO PRACTICE IN A CLASSROOM ENVIRONMENT

By

Filipa Caria Henriques Guerra

Master Thesis presented as partial requirement for obtaining the European Master of Science in Information Systems Management: Master's degree in Information Management, with a specialization in Information Systems and Technology Management (Nova IMS) and Master's degree in Business Informatics (SEB LU)

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

Filipa Caria Henriques Guerra

Oeiras, 28th of October 2022

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ABSTRACT

Technology in education, as in most pillars of society, represents a trend for the new era. Often referred to as Smart Education, the integration of technology into learning environments with the goal of enhancing the experience for students and teachers has been of growing interest to learning institutions. The emergence of a heterodox theory of learning, connectivism, has come to prioritize the incessant search for new and accurate information and, consequently, the capacity of the learner to build knowledge through the connection of nodes within the chaos of contradictory opinions. Being connectivism associated with the reality of an e-learning context, it remains challenging to adapt it into a setting of presential university classes. The model developed in this paper is a proposition of how to fill this gap, hence answering the question of *how to put connectivism into practice in a campus environment*. The framework, which combines the students' self-research, and online interaction with their peers through social media platforms, culminating in physical classroom discussions, reflects the connectivism principles and is beneficial for the majority of students. Unlike most connectivism-inspired class dynamics, here, the professor's role is critical, with the responsibility of moderation and capacity to assess whether the students have been successful in building knowledge through their connections. Although the aim of the study is to apply connectivism principles in a physical campus, the relevance of work-oriented social media platforms in this model is undeniable.

KEYWORDS

Information Age; Education; Learning Theory; Connectivism; Social Media Platforms; Class Discussion.

Sustainable Development Goals (SGD):

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LIST OF ABBREVIATIONS AND ACRONYMS

DSR Design Science Research

FR Functional Requirements

IoT Internet of Things

LT Learning Theory

NFR Non-Functional Requirements

SC Smart Classroom

1. INTRODUCTION

The first steps of formal education in society – which involves a systematic process of teaching and learning provided by learning institutions – dates back to the early ages of human civilization (Eskelson, 2020). Education as we know it today has constantly been improved and adapted to the evolution of society. The act of learning began by simply memorizing what was verbally expressed by a teacher to introducing a reusable writing tool as a first technological innovation. As of today, with remarkable developments in technology and learning theories, there are innumerable innovative materials and techniques at the disposal of institutions (Muttappallymyalil et al., 2016). The last decades have been referred to as the Information Age, where information is quickly disseminated and considered a valuable resource when allied with the usage of information technology. This modern age has brought significant changes in many aspects and stimulated an ever-growing interest in employing technological solutions to achieve smart areas, where services are optimized to increase the quality of life of the general population. Additionally, the constraints of the Covid-19 pandemic have accelerated these technological advancements, drawing special attention to the role that technology can have in aspects of our social lives, including learning environments.

Not only did the educational system paradigm take a shift regarding the integration of new technological solutions, but also concerning new learning theories. The Information Age brought to the discussion whether the most traditional learning theories - behaviorism, cognitivism, and constructivism - were adequate for this current reality. Consequently, George Siemens developed what he named connectivism, a heterodox learning theory that differs from the remaining by stating that learning is a process based on finding the connection and integration of several sources and pattern recognition. Unlike the previous theories, connectivism theorists defend that acquiring knowledge is not limited to the internality of the individual, but to the exploration of chaos and the ability to recognize relevant information (Siemens, 2005). In practical matters, connectivism allows students to decide on the most appropriate learning sources while developing discussion, collaboration, and critical thinking competencies. The ability to access large data sources in and outside the learning environment creates a valuable dynamic between the student, the professor, and the resources (Wordu & Azery, 2021).

Emerging in a topic as comprehensive and studied as Smart Learning Environments and integrating the learning theory of connectivism into it is not as clear-cut as it seems. This is because, although connectivism is associated with the Information Age, it is challenging to associate its practicality with the physical context of a campus. Doubts still prevail on how to make connectivism a reality associated with face-to-face teaching and learning through the integration of technological trends, and that is where this study intends to focus.

This paper aims to contribute to the modernization of presential education, by applying the learning theory for the Digital Age in classrooms, and not only in e-learning scenarios. The main research question to be answered is, then, "*how to put connectivism into practice in a campus environment?*".

To achieve this, a model will be developed, introducing an online platform to be put to use within a university class, that will support collaboration inside the classroom, and, eventually, attain all eight principles of connectivism.

As a research methodology, the Design Science Research method was used, as it allows the identification of relevant problems and opportunities for improvement in the adoption of connectivism as a learning theory in university classes. This will result in a connectivism-inspired model to be applied at university campus classes, intending to benefit students and professors. Six short interviews of two questions each will be conducted with two students, two professors, one PhD in Education and one Software Engineer, intending to validate, as well as explore the existent benefits and challenges of the presented framework. This collection of pertinent opinions will enrichen the answer to the research question.

1.1. Thesis Structure

The thesis is divided according to the following chapters:

1. **Methodology**: this chapter will explain how the research will be conducted, specifying the necessary procedures to take according to the chosen research method (Design Science Research), in order to attain the objectives of the study;
2. **Literature Review:** this chapter represents a fundamental part of the methodology, as it will allow a deeper understanding of the topic of technology in education and connectivism and will consequently lead to finding a research gap;
3. **Model:** this chapter will thoroughly elaborate on the description of the model to implement, which aims to contribute to solving the problem of difficulty in employing connectivism-based learning on a physical campus. Here, there will be presented a range of functional and non-functional requirements regarding the software to support the model. Additionally, three renowned social media platforms that are close representatives of the selected software requirements are discussed;
4. **Results and Discussion:** this chapter assesses the viability and quality of the model by including six short interviews with relevant stakeholders and consequent reformulation of the model. The chapter proceeds with a discussion of the obtained results;
5. **Conclusions and Important Remarks:** this chapter identifies the main steps and findings of this paper, additionally stating study limitations and future work to be done.

2. METHODOLOGY

For the development of what is proposed in this project, Design Science Research stands as the most appropriate approach, as it has been widely used and has helped numerous researchers to contribute with relevant inputs to the literature. This research method is applied when there are intentions of creating an innovative artifact to address a human need, which is accomplished through the concretization of sequential steps (Venable & Baskerville, 2012).

The identification of a research problem (lack of application of connectivism into a physical classroom) that requires the delivery of a solution (the framework proposal of the interaction with an online platform, the students and the professor as an artifact) settles in the rigorous guidelines that DSR presents. This methodology will allow a systematic and time-saving process to accomplish the desired results (Venable & Baskerville, 2012).

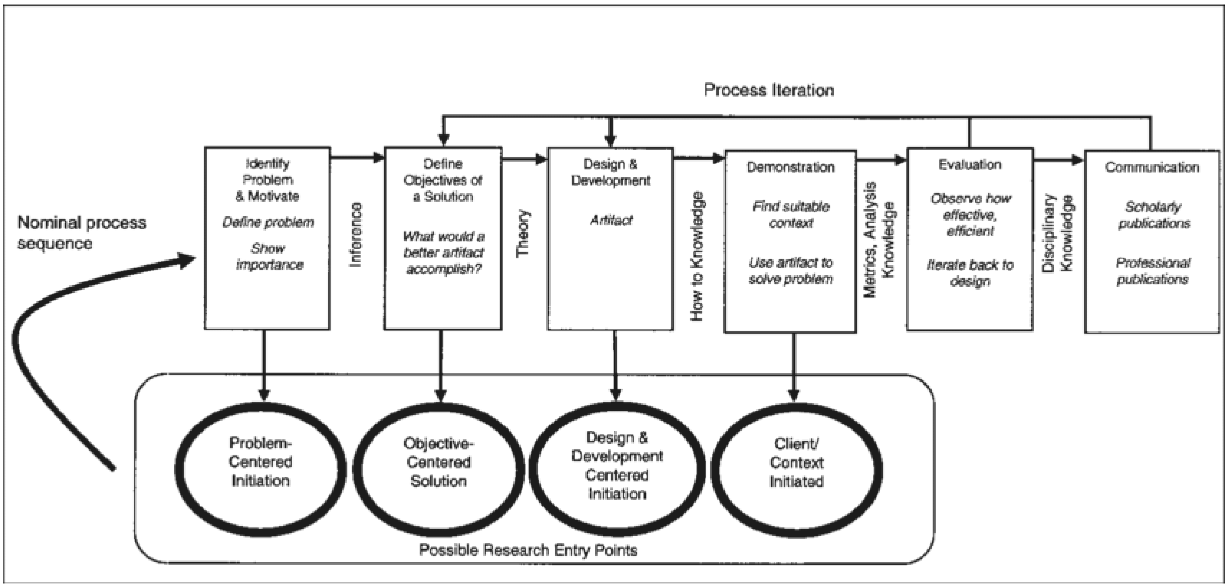
2.1. Design Science Research

Design Science Research is a methodology applied in scientific research, not only in information systems but in other sciences, to rigorously propose new or enhanced artifacts in the form of prescriptive solutions to identified research problems. DSR has particularly been attracting researchers for its nature of putting together the theoretical and practical aspects of the research and for presenting a systematic framework for reaching solutions for identified problems (Aken, 2004). The thorough following of the steps in this method will help researchers find answers and, most importantly, generate valuable knowledge in the literature that will be beneficial in filling research gaps (Goecks et al., 2021).

Inside the sphere of DSR, there have been proposed distinct process models, which are applied according to the needs of research. For instance, one of them is intended by Vaishnavi and Kuechler in (Kuechler & Vaishnavi, 2008) when one wants to act on a more abstract theory-based environment, other is proposed by Hevner in (Hevner et al., 2004) which concerns a more practical approach, suitable for building artifacts that will act on real environments, and finally, the most widely used was proposed in (Peffers et al., 2007) by Peffers. The latter methodology will be put to use in this research as it provides a complete and generalized overview of the previously presented models. To develop the methodology to carry out the research, Peffers has gathered consensus on previously presented process activities which has consequentially resulted in six activities: Problem identification and motivation, Defining the objectives for a solution, Design and development, Demonstration, Evaluation and Communication.

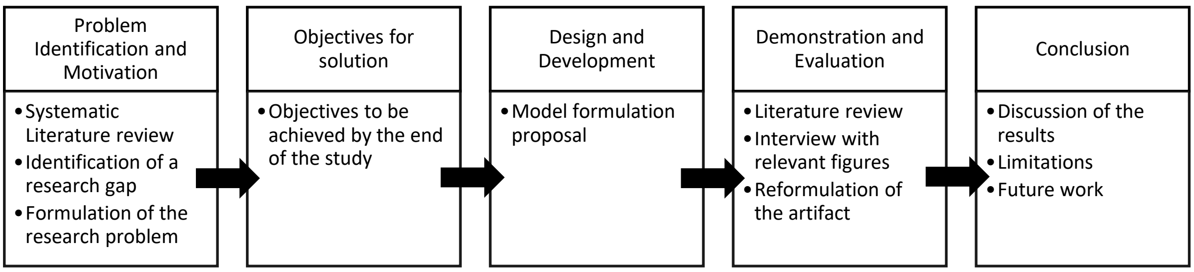
The first step, "**problem identification and motivation"**, has a problem-centered approach underlined, and it involves the identification and definition of a research problem that requires the development of a solution. Often during this phase, researchers conceptualize the problem, in order to better visualize the importance of the solution. Secondly, the activity "**define the objectives for a solution"** settles on an objective-centered solution and aims for the quantitative or qualitative detailed presentation of the objectives of the artifact, as an attempt to solve the problem stated above. The **"design and development"** phase, initiated by a design- and development-centered approach, comes to further elaborate on what was proposed in the previous step, ultimately creating the so-called artifact. It seeks the development of the solution through the implementation of appropriate techniques, including the prototype of how the artifact will work (functionality and architecture), proceeding to its actual development. Moving forward, the **"demonstration"** follows a client/context solution and seeks to understand how the artifact will solve the stated problem, either through experiments, case studies or simulations. Subsequently, the created artifact will need to go through an "**evaluation"** phase, where its viability will be assessed, which often includes system performance measures. It frequently happens that the feedback obtained in this phase will redetermine the construction of the artifact, making researchers return to the third activity. Finally, the **"communication"** activity fosters the diffusion of the knowledge obtained throughout all the previous phases, which can occur in the form of publications. As the picture below illustrates, the process follows a nominal sequence that can suffer iterations if needed (Peffers et al., 2007).

Illustrative figure 1 - Demonstration of DSR Methodology proposed by (Peffers et al., 2007)



2.2. RESEARCH STRATEGY

This chapter will explain how this research will consider the activities proposed above by Peffers. It will provide a brief description of what needs to be executed in each step, in order to achieve a viable solution to the stated research problem. The diagram below summarizes the research strategy employed in the study.



In the first step of the DSR process – "**Problem Identification and Motivation"** - a research problem needs to be identified, and such will be possible by conducting a literature review that will cover the trends of technology in the educational sector. It is intended to particularly focus on connectivism as a learning theory, e-learning, and in-campus technology. By exploring the current state of these matters, a research gap will be identified, and a research problem will be further defined.

A systematic literature review, following the PRISMA method will be applied in this study, which will contribute to a better finding of appropriate articles in large databases. Subsequently, an article and journal bibliometric analysis performed with VOSViewer will allow for an understanding of technological trends in education, namely IoT, LMS, blockchain or AR/VR.

After having identified a relevant research problem, in the second phase **"Define the objectives for a solution",** there should be defined the objectives to be attained with the implementation of the artifact, and explain how it can solve, or help improve, the problem of lack of application of connectivism to a physical learning environment. The artifact will essentially be a model that represents connectivism in a situation of presential classes in a university context.

After clearing these objectives out, the "**Design and Development**" phase should be divided into the two following steps:

1. Describe the functional and non-functional requirements of a new system;
2. Describe other platforms placed in the market that are suitable options to solve the research problem;
3. Conceptualize in a BPMN diagram the dynamics between the system and the users (in and outside the campus); and,
4. Describe the dynamics that illustrate the application of connectivism principles into hybrid education (online interaction through the platform and in person classes)

The **"Demonstration"** and "**Evaluation**" phases will culminate in the conduct of interviews with open questions, which are intended to ascertain the implications of the artifact on education. To this end, it is adequate to explore perceived advantages, disadvantages, suggestions and the impact that the framework would have on a real-life scenario. The in-depth interviews will follow a short script and allow the interviewer to conveniently deviate from the script if needed and will differ according to the intervenient – university student, professor, education expert, and software engineer.

The viability and quality of the artifact are also determined by the interviews as well as the literature review performed earlier, which reflected on the impact that some features of what is presented have on education.

The final part of the DSR, **Conclusion**, includes the presentation of a discussion of the obtained results, which will fulfill the goals of the study. Moreover, there will be stated the limitations of this study, and future work, that could not be approached within the constraints of this research. The dissemination of the findings of this study will be done through the publication of this paperwork and formulating a post on a personal blog, where the theme of technology in education is applicable.

3. LITERATURE REVIEW

The following chapter focuses on gathering a structured knowledge about the relevant topics of technology in education and learning theories that exist in the literature. The following findings aims to find research gaps in this theme thus stating the research problem and to be ultimately achieved.

3.1. LITERATURE REVIEW RESEARCH QUESTIONS

Firstly, it is considered extremely important to analyze the educational system in its general form. This includes not only seeking a clear comprehension of what the current trends in education are but also understanding how this sector has evolved, namely by identifying triggering events or changes in practices brought by the Information Age. It is equally important to discuss the most significant learning theories and their fundaments. Such will be clarified by answering the research question, *what impact has the Information Age had on education?*

After having identified the paradigm of the education sector in light of the Information Age, it becomes pertinent to acquire insights into the various technological innovations that are currently being employed on and off campus to support education. On the one hand, this could include IoT devices, blockchain, 5g, AR/VR solutions, and on the other hand, software that operates on online platforms or smartphone applications. For that, the following question must be explored: *Which are some of the most relevant technological trends and online platforms used in Higher Education?*

It is, then, appropriate to recognize the impact that connectivism and online educational platforms can have on society. Thus, it is fundamental to understand their benefits and challenges, according to either scientific research or the opinions of different stakeholders. With this intention, it should be asked, *what are the perceived benefits and challenges of the application of (1) connectivism and (2) online platforms in education?*

Table 1 - Literature Review research questions and objectives.

	Research Question(s)	**Objectives**
LRQ1	What impact has the Information Age had on education?	Identify the change of paradigm that education faced in the last years.
LRQ2	Which are some of the most relevant technological trends and online platforms used in Higher Education?	Explore the usage of technological trends and platforms used to enhance education virtually and in person.
LRQ3	What are the perceived benefits and challenges of the application of (1) connectivism and (2) online platforms in education?	Assess the overall perceived benefits and challenges associated with the implementation of (1) connectivism principles and (2) online platforms from different stakeholders' perspectives.

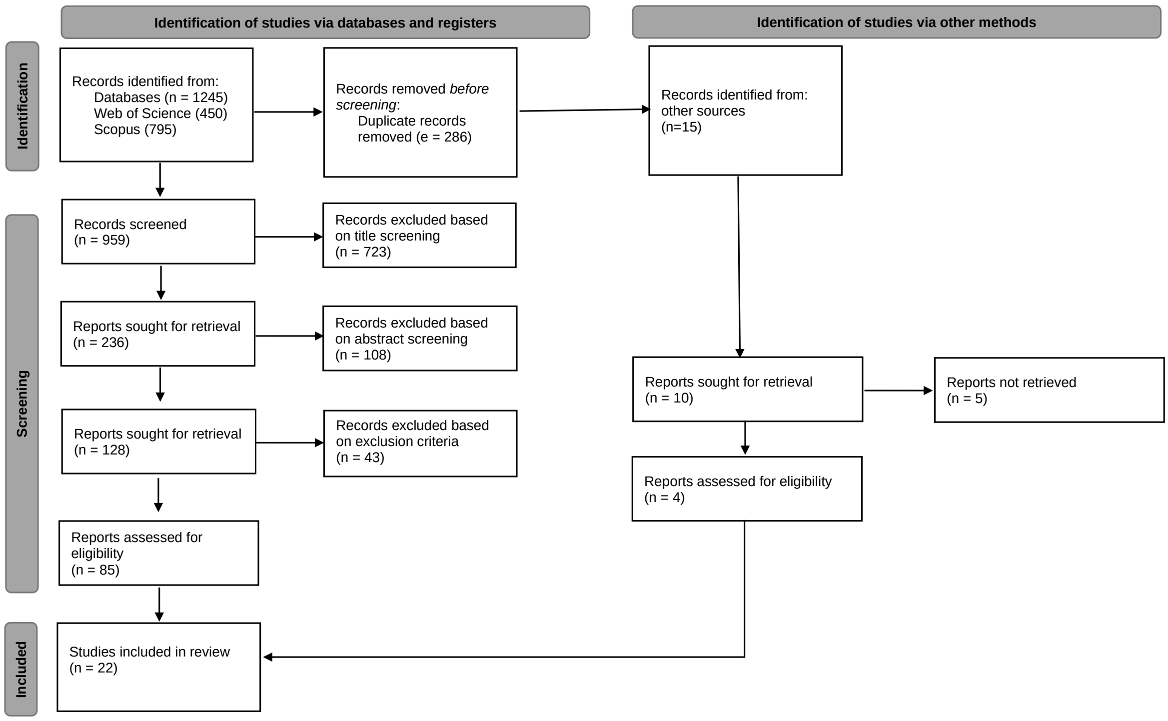
3.2. Systematic Literature Review

The systematic literature review was carried out with the PRISMA methodology, which consists of a series of steps for systematic reviews and meta-analysis.

3.2.1. PRISMA Results

The PRISMA flow diagram serves as a sequential step demonstrator of the creation of the final dataset, which will include research and conference articles that will then be used in the Systematic Literature Review. The first stage refers to the identification of pertinent papers through the search in two databases – Web of Science and Scopus – and the inclusion of articles perceived as relevant beforehand. The initial retrieval resulted in 1260 publications (795 from Scopus, 450 from Web of Science and 15 from additional sources). The following actions included removing duplicates (e = 286) and, consequently, title and abstract screening. The first step indicated that articles whose titles were nonrelated to the study should be removed (e = 723). In the second step, the abstracts of the remaining articles were read and kept those referring to articles were considered in line with the objectives of this study (e = 108). The third step aimed to exclude the articles outside the inclusion criteria. These criteria apply to journal articles written in English and included in Q1-Q2, which were peer-reviewed according to the Scimago ranking (e = 43). The remaining articles were fully assessed, and there were excluded those that were considered repetitive considering kept articles or too technical, which did not meet the scope of this research (e = 63). In the end, the study was ready to proceed with 22 papers, the majority of them being journal articles, and one from a conference.

Illustrative figure 2 - PRISMA 2020 Flow Diagram.



3.2.2. Journals' Analysis

The 21 final extracted papers are distributed in a total of 23 journals, namely Sustainability (2), Technology, Knowledge and Learning (2), Journal of Computing in Higher Education (2), Computer Applications in Engineering Education (1), Heliyon (1), IEEE Access (1), International Journal of Instructional Technology and Distance Learning (1), International Journal of Mathematical Education in Science and Technology (1), International Journal of Online and Biomedical Engineering (1), International Journal of Social Science and Education Research (1), International Journal of STEM Education (1), International Journal on Interactive Design and Manufacturing (1), International Review Of Research In Open And Distributed Learning (1), Journal of Universal Computer Science (1), Resonance (1), Technology in Society (1), Thinking Skills and Creativity (1), and Wireless Communications and Mobile Computing (1). Most journals are ranked in the first quartile (7), followed by the second quartile (6), while the remaining are not classified yet by Scimago (2) or in the third (1) and fourth (1) quartile. In the table below, there can be found information regarding the top 3 journals presented in the study:

Table 2 - Top 3 Journal details

Journal	**No.**	**Quartile**	**Field**	**Publisher**
Sustainability	2	Q2	Energy, Environmental Science, Social Sciences	MDPI AG
Technology, Knowledge and Learning	2	Q1, Q2	Computer Science, Engineering, Mathematics, Social Sciences	Springer Science + Business Media
Journal of Computing in Higher Education	2	Q1	Social Sciences	Springer US

3.2.3. Articles Analysis

In order to get a clearer perception of the patterns associated with the final articles, there was applied VOSviewer, which consists of software that originates network-based maps with imported data. As two of the articles were not extracted from databases that include papers with abstracts or keywords, only 20 articles were considered for this analysis.

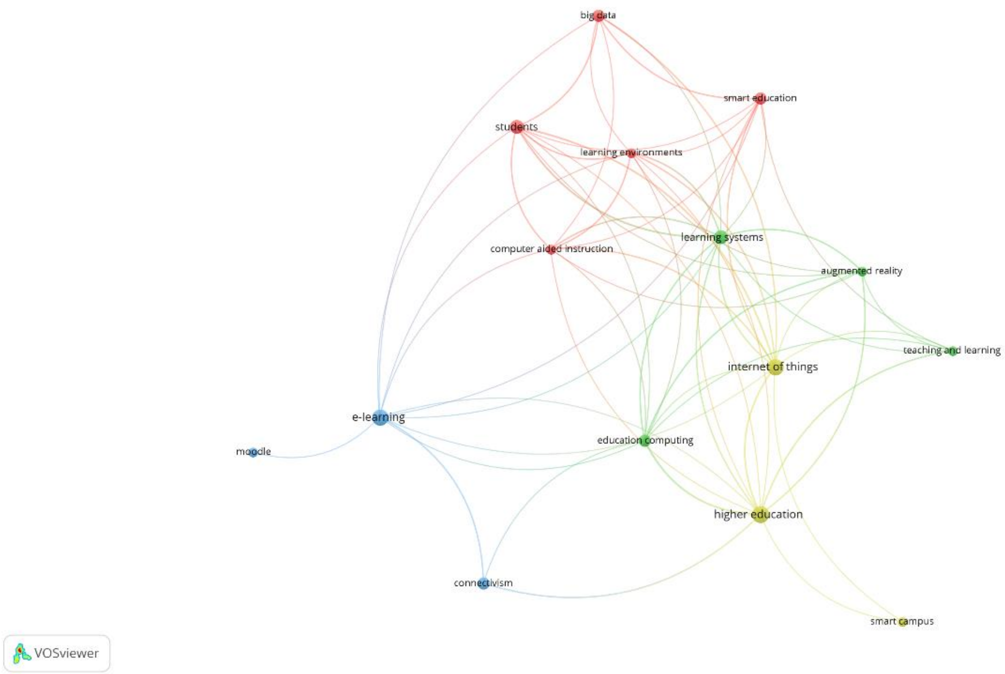
The first analysis performed was a keyword co-occurrence analysis. The preferred method was full counting, and out of 160 screened terms, 25 were initially accounted for in the analysis. This number was later reduced to 15, as there were found redundancies within the words, for instance, "Internet of Things and "IoT". The minimum of co-occurrences was set to two.

Table 3 - Keyword co-occurrence

Journal	Occurrences	Total Link Strength
Internet of Things	5	26
Higher Education	6	25
Learning Systems	4	25
Students	4	22
Education Computing	3	18
Computer Aided Instruction	2	17
Learning Environments	2	17
E-learning	5	16
Augmented Reality	22	14
Big Data	3	14
Smart Education	3	14
Teaching and Learning	2	9
Connectivism	3	6
Smart Campus	2	4
Moodle	2	2

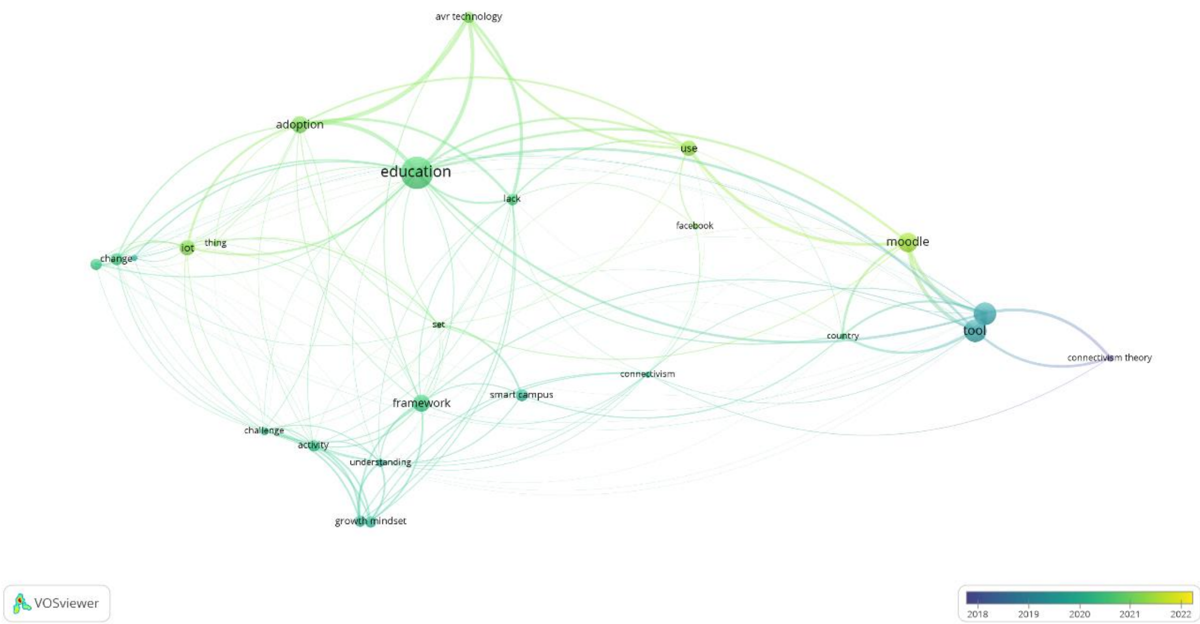
"Higher Education" was the keyword that represented the most occurrences (6) and "Internet of Things" was the strongest link (26). Additionally, the most relevant keywords include "Learning Systems" (4 occurrences, 25 total link strength), "Students" (4 occurrences, 22 total link strengths), "Education Computing" (3 occurrences, 18 total link strength) and "Computer Aided Instruction" (2 occurrences, 17 total link strength). The four formed clusters can be denominated Smart Campus, representing the yellow cluster, Connectivism as the blue cluster, Smart Education as the red cluster and finally, Learning Management Systems (LMS), which corresponds to the green cluster. From the mapped association links observed in the picture below, there can be concluded that "Internet of Things" is associated with all the keywords except for "Connectivism" and "Moodle", and the same situation can be identified with "Higher Education" regarding "Big Data" and "Moodle". Contrarily to the other keywords, "Moodle" is only associated with one cluster (blue) other than its own.

Illustrative figure 3 - Keyword co-occurrence network visualization



Another feature of VOSviewer is allowing the creation of overlay visualizations, mainly used to show trends over time. In this case, its purpose consisted of verifying the relevance of the terms included in the abstract of the articles, their associations, and time patterns. The method chosen was once again full counting, and the minimum term occurrence was set to 5. As observed below, from the 25 extracted terms, “Education”, “Framework”, “Tool”, or “Smart Campus” are some of the ones used the most in the abstracts. There can be noticed that the term “Moodle” or “IoT” are most used in recent years, in contrast with terms such as “Connectivism Theory” and “Tool”, with are associated with previous years.

Illustrative figure 4 - Term co-occurrence overlay visualization



3.3. DISCUSSION

The chapter proceeds with a comprehensive literature discussion, intending to answer each of the first three proposed literature research questions.

Plenty of articles refer to the changes that have occurred in the educational sector with the emergence of the Information Age (**LRRQ1**: *What impact has the Information Age had on education?).* The increasing development of the world's connectivity brought by large investments in technology has determined the transition from the Industrial Age to the present era of the Information Age, or Digital Age. The rapid dissemination and access to information have facilitated how the world communicates and builds knowledge upon it. The internet has come to eliminate temporal and location differences, thus fostering globalization. Information has become one of the most powerful assets, having information technology affecting the functioning of various sectors, namely the educational one (Büyükbaykal, 2015). The concept of Education, which comprises the acquisition of knowledge in various forms, has been integrated into society since the first steps of civilization, and it has been evolving ever since. As it can be considered a very broad term, UNESCO has defined two types of education – formal and non-formal. Formal education regards the educational system of a country, where learning is centred around structured processes and expects the fulfilment of officially recognized qualifications by competent authorities. In its general form, formal education is offered by professors in certified organizations, public or private. Informal education comprehends workshops, seminars, or other non-recognized activities (UNESCO Institute for Statistics, 2011).

The current seeking for smart environments that aspire to proportionate societies with better living conditions is increasing at a fast pace. Such means that globally, the needs of students have likewise evolved, and new practices and tools are required to operate in learning scenarios. The literature argues that Smart Campuses are smart cities on a smaller scale that differ in structure and objective. Thus, they incorporate three basic elements: personalized services, information services, and environmental platforms (Ahmed et al., 2020). Technology is now seen as an influential instrument inside the classroom that holds power to transform how learning and teaching take place. Technologies such as the Internet of Things (IoT), Cloud, Artificial Intelligence (AI), Virtual Reality (VR) or Blockchain are turning lessons into more interactive and two-way interactive events between teachers and students (Agarwal et al., 2021).

Learning theories are models that describe the form in which the learning process occurs. Throughout time, each of them has been subject to a strong body of research and contestation. It is worth mentioning that oftentimes researchers defend that learning incorporates two or more theories. Considering the four main LTs, two categories can be recognized: objectivist (behaviourism) and constructivist (cognitivism, constructivism and connectivism) theories (Campbell et al., 2020). Behaviourism suggests that interacting with the environment and responding to its stimulus creates (observable) behaviour-based knowledge. Objections towards this theory referred to how the attained knowledge did not consider each person's characteristics and inherent thoughts. Constructivist theories came to refute this objective view of learning. Cognitivism learning relies on memory and the internal association of patterns, stating that knowledge is created and processed in one's mind (Agarkar, 2019). Constructivism, one of the most widely defended LTs, alleges that knowledge is built upon previous knowledge that the individual has acquired, and new information is consequently assimilated through the learner's own experiences (Campbell et al., 2020). Connectivism theorists have identified as a limitation of these LTs the fact that they put the learner exclusively in the centre of the learning process – not considering that this process can occur outside, for instance, through technology.

The heterodox theory of connectivism introduced by (Siemens, 2005) came to add to the previous theories about the impact that the Information Age has had on learning, stating that the advances in technology replace most of the cognitive tasks that were once performed by learners. The learner's task is now to create meaningful connections by recognizing patterns in networks characterized by chaos. The principles of connectivism are defined as the following: (1) «Learning, and knowledge rests in diversity of opinions»; (2) «Learning is a process of connecting specialized nodes or information sources»; (3) «Learning may reside in non-human appliances»; (4) «Capacity to know more is more critical than what is currently known»; (5) «Nurturing and maintaining connections is needed to facilitate continual learning»; (6) «Ability to see connections between fields, ideas, and concepts is a core skill»; (7) «Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities» and (8) «Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision» (Siemens, 2005).

The process of students connecting to various networks via technology is mostly achieved in online settings, where they can find multiple sources of information and social networks, and have the power to decide what is, for them, the most valuable information (AlDahdouh, 2020). MOOCs (Massive Open Online Courses) have been popularized in the last few years, as they are platforms with extended content about certain topics that can reach a large audience through the internet. These often offer the display of digital content in the form of text, audio, videos or discussion forums, which goes in line with the connectivism claim that technology is the basis of the connection in the network (Jacobsen, 2019). Nevertheless, some researchers argue that connectivism learning prepositions are only adequate in e-learning scenarios and are not applicable to the extent of a classroom (AlDahdouh, 2020).

The answer to the second research question (**LRRQ2:** *Which are some of the most relevant technological trends and online platforms used in Higher Education?)* comes with a combination of multiple technological solutions found in the literature. Smart learning environments, i.e. smart classrooms, leverage formal and informal education, creating new challenging and customized contexts for students. Learning outcomes can be maximized with an integration of physical and virtual classrooms that allow autonomous and personalized services, considering real-time information, personal feedback and collaboration tools (Iqbal et al., 2020). For instance, students can take advantage of IoT devices, which include computers and tablets, e-books or digital scanners and other devices to promote digital literacy, creativity and collaboration. Professors can apply diverse software and IoT options for examination purposes or training. The latter can become richer by incorporating context-related technologies into lectures, video conferencing with third parties or even by guiding students through self-efficient methods of learning (Mircea et al., 2021).

Other trends in SC include the use of blockchain technology to foster data protection, especially with the increasing danger exposition that IoT usage brings. Consequently, (He et al., 2021) discuss a blockchain-based solution to prevent unwanted data access. It comprises a data collection system that ensures the correct transfer of data to the database, a MongoDB database that contains a model which assures permissions in the blockchain, and a strict system that attributes roles and is managed by a blockchain unit.

E-learning technologies have been popularized in recent times, as they eliminate geographical boundaries and allow an efficient manner of disseminating information. As mentioned previously, connectivism highly encourages learners to seek meaningful connections, which are often found in learning management systems, platforms enablers of e-learning scenarios. These are considered by (Mpungose & Khoza, 2022) to be the key to conducting non-formal learning, which accounts for the learner's individual experience. The chat option in these platforms was proven to be a great asset for feedback and content sharing. One of the most widely used LMS is Moodle. A study by (Gamage et al., 2022) has reviewed this platform as an effective method to establish the connection between the teacher and their students. The teachers gain larger flexibility in their tasks, as they can post assessments and display modules of content on this LMS, and creativity in the method of delivering knowledge adequate to the nature of the content. It is also beneficial in saving time in some tasks, namely the evaluation of students that can be numerically provided and summarized if the assessments are conducted there. Moodle's most used features include Quizzes (as a form of assessment), workshops, and multimedia content, such as videos that can be externally attached. Moodle as an LSM has been proven to create significant engagement and satisfaction rates among students. Blackboard is a tool that acts in hybrid environments that allows the posting of keynotes during class, which can then be sent to its participants after the class via email. It is also possible to throw assignments and grading. The tool offers students with flexible options for organizing schedules and course distribution, which is seen as an essential feature in the student's learning (Aljawarneh, 2020).

The connectivism-inspired encouragement of students to pursue their own learning direction can be supported by Web 2.0 learning tools. (Mohamed et al., 2018) studied the effect of the incorporation of Facebook as a widely used social network allied with connectivist principles and students' achievements. The potential of Facebook for increasing the quality of the learning process for students and teachers through the ease of connecting is confirmed in the study. The social network was proved to positively impact autonomy, diversity, interactivity and openness.

The authors (Halimi & Seridi-Bouchelaghem, 2019) suggest a new web 3.0 platform that allows the creation of groups of various interest areas, becoming a focal point between teachers, students, and experts. There, they can access and share relevant content, interact with users, and find many sources of information. All student behaviour and interaction are recorded and converted into knowledge about their learning. In this study, the use of this technology proved effective in increasing participation and interest. Furthermore, text mining applied to LMS can help retrieve valuable information about the students' posted content relevance, discussion coherence, feedback, or other critical statistics (Mohammed et al., 2021). Gamification in learning was explored by (Petrović et al., 2022). In this research, it is stated that games in an educational context are benefic, as they are challenging and promote cognitive capacities. The attempt here was to present a gamification solution in the classroom that integrated both physical sensors to allow VR experiences and digital content, such as puzzles or quizzes to be solved on online platforms. Lastly, (Villegas-Ch et al., 2020) studied the inclusion of a Chatbot, an AI application that simulates conversations that could be done by humans. The chatbot must have algorithms capable of interpreting the user's feedback, mainly through keywords. This technology aims to increase interaction, personalized content sharing, and autonomy. This implementation revealed positive results, as it increased class participation and decision-making among students. The authors (Ekici & Erdem, 2020) use mobile learning to foster inquiry skills among students. Mobile learning can play an important role in creating flexibility in the place and time students access course materials, encouraging collaboration and deep learning. The proposed mobile application allowed students to create projects and access others created by their peers, having the option to include multimedia content. It was expected from students that, after accessing the projects, they formulated research questions and hypotheses, insert these data and consequent results on the application. A discussion section was made available for students to exchange impressions about the projects. The results pointed out that the discussion, project visualization, comment section and video and picture attachment features were among the most used on the application.

Proceeding to (**LRRQ3**: *What are the perceived benefits and challenges of the application of (1) connectivism and (2) online platforms in education?* and as described earlier, technology like IoT and AVR provides students with unique and personalized experiences, according to their curriculum and degree of knowledge. Students believe in the potential of these solutions to revolutionize the educational sector (Matsika & Zhou, 2021). The author (Jacobsen, 2019) studied MOOC adoption among students. It was concluded that they revealed high interest and curiosity in the first weeks of usage, with a declination of this factor after the completion of two tasks. Such can be interpreted either as a drop in interest or completed assimilation of the content. As none of the students had completed the totality of the course proposed in the MOOC, maybe because of total autonomy in the learning content, the access place and the time to do it, a stronger strategy for its adoption should be rethought. A study brought by (Ahmed et al., 2020) highlights some challenges to be taken into account by different stakeholders, namely the lack of widespread examples, which puts investing in this type of smart technology at high risk. Adding to this, the elevated installation and maintenance associated costs are factors to consider. As smart applications strongly rely on data usage, data protection assurance is an important challenge. Other challenges pointed out by (Agarwal et al., 2021) refer to the higher ease of academic cheating with the use of some technologies, possible e-waste caused by the increasing device circulation, or misuse of data for institutional self-benefit. The advances in technology also came to emphasize disparities between world regions regarding digital competencies and preparation. This also means that most developing countries show reluctance to accept smart infrastructure's long-term benefits. Even though it is clear that wealthy countries will reap the benefits of these advancements, investment from outside parties toward developing countries should be made in terms of infrastructure, hardware, and software (Matsika & Zhou, 2021).

Teachers perceive teaching in a connectivist model as a facilitating and intermediary task that fosters the growth of their students. It is, then, easier to assign content and tasks via online platforms, which leaves them with more time to develop relevant responsibilities (Wordu & Azery, 2021). The mobile application referred to in (Ekici & Erdem, 2020) has triggered positive perceptions in students. The preferred outcomes by the students were the easiness of exchanging ideas with the class and discussion, the development of scientific process skills, fast communication, motivation, and the development of technology usage skills. On the downside, students pinpointed the increase of competition and criticism, the pressure to stay active on the Application, and issues related to the requirement of internet connection and possible device technical problems. The study (Ulla & Perales, 2021) focused on understanding students' views on the integration of Facebook as a remote learning tool during the Covid-19 outbreak. The majority of them highlighted that it fostered their independency and creativity in learning, although there were pinpointed some negative aspects. These included the lack of support due to distance, interaction, difficulty in focusing or instability in internet connection. The authors mention that online learning can hinder collaboration among students, as including collaboration tasks in a virtual context is not easy. It is stated that, with the stabilization of the pandemic, schools must invest in enhancing their campuses with new technology solutions and rethink their curriculum.

Connectivism as a learning theory is, nonetheless, perceived as an almost exclusively online premise. Learners are expected to explore different sources of information and to be able to create knowledge in a network by confronting contradictory opinions. Often this search for information is facilitated by accessing the Internet, either through unlimited access to articles, websites and multimedia content or through the ease of interaction with peers. The theory states that the students do not need to follow a structured set of modules to learn but rather discover their own path. Nevertheless, the full autonomy that is conceived to students in regard to choosing their own learning content can cause them to lose motivation and focus. Thus, adapting connectivism to the reality of hybrid education (that merges virtual and presential schooling) can be seen as an appropriate solution. In this sense, incorporating the principles of this theory on a physical campus can also benefit from the varied uses of the internet, with the advantage that the personal component, which is enhanced by in-person classes, is not lost.

Additionally, the Covid-19 crisis exposed existing flaws in conventional education systems – outdated teaching materials or lack of digitalization. In turn, these can also be translated into opportunities for schools and other learning institutions to adapt to the constantly changing educational needs of students (Abu Talib et al., 2021) or even to recreate teaching itself.

This study finds relevance in proposing to learning institutions and interested entities an artifact that aims to serve as a bridge to bring connectivism to the prospects of a physical classroom, connecting it with virtual education. The main goal is then to conceptually develop a framework that states the dynamics of an interaction representative of connectivism on a physical setting in order to enhance the educational outcomes of university students. The technological component of the framework will regard a conceptually proposed software that will run on a mobile application, that can represent existing digital platforms. Thus, this research paper intends to answer the main question, *how to put connectivism into practice in a campus environment?*

The table below lists the main research question (RQ), as well as two sub RQs and respective objectives that will support the fulfillment of the main objective:

Table 4 - Research questions and objectives

	Research Questions	**Objectives**
RQ1	**How to put connectivism into practice in a campus environment?**	**To conceptually develop a framework that represents connectivism principles and applies them at a university campus classroom in order to enhance education outcomes**
RQ2	How to develop a technological platform to foster the creation of meaningful connections in the learning process inside and outside a campus?	To propose new and existent digital platforms that foster the development of autonomous research and active interaction skills among the student community, both online and in-class
RQ3	How to define the role of the professor in the context of the proposed framework?	To characterize the role and responsibilities that the professor has in the context of the connectivism classroom framework

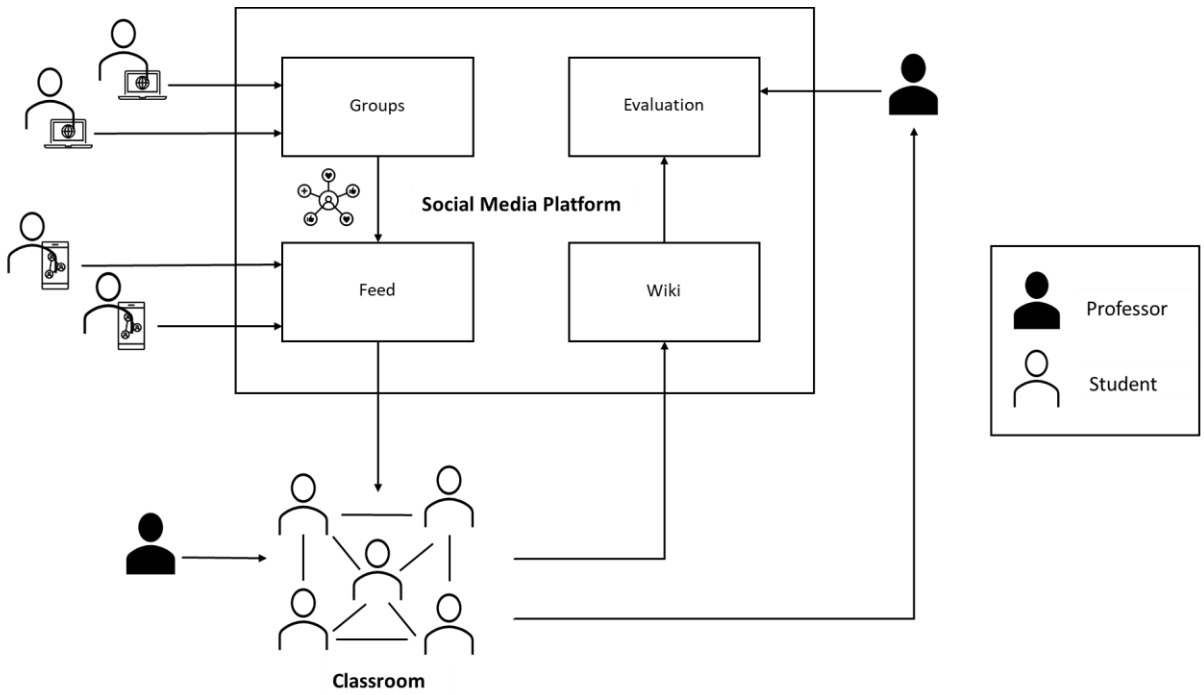
4. A MODEL FOR USING SOCIAL MEDIA PLATFORMS TO SUPPORT A CONNECTIVIST APPROACH ON CAMPUS

The model to be developed intends to draw inspiration from the connectivism learning theory and apply it in a classroom setting, creating new roles for the students, professors, and technology. On this chapter there will be described different alternatives for the above-mentioned.

4.1. MODEL

The diagram that follows is an overview of an illustrative representation of an interaction in a school context, based on connectivism. The interplay relies on several intermediaries, starting with the students' individual search for content in online search engines, such as Google or Bing. The second intermediary is a private online social network, which functions as a forum where students can share what they have learned from their previous research, as well as interact with the posts of their peers. The knowledge base acquired on this platform is then transferred to the classroom, where the professor will moderate a discussion in which the students are the main actors, who will refer to others' arguments and posts previously read on the social network. The students must return to the platform after the class on campus is over to participate in the formulation of a summary of the content covered, which works like a wiki page, consisting of a thread integrated into each group. After that, the cycle closes with the attribution of individual (and, optionally, group) grades, which are inserted by the professor on a specific section of the digital platform.

Illustrative figure 5 - Model for using Social Media Platforms to support a connectivism approach on campus



4.2. User's Interaction with the Online Platform and inside the Classroom

A diagram, included in Appendix A – Representation of the User's Interaction With the Platform, determines a detailed guidance on how to use the model, providing a general understanding of the interaction of the user with the platform, in and outside of the classroom, independent from the technology to adopt. The flowchart was designed using BPMN 2.0 (Business Process Model And Notation), a standard language for the representation of business processes. This notation is particularly helpful either for stakeholders to easily understand the behaviour of business processes and for developers to implement the technology behind such processes (Object Management Group, 2010).

The diagram represents a situation in which the user intends to open the application and use it. If the user does not have an account yet, they should create one by inserting personal data (mandatory and/or optional). Mandatory data refers to a unique username, e-mail address, full name, date of birth and school. The sign-in/log-in can also be carried out using the institution's credentials, although it is subject to the university's approval. After validating their account on their email or mobile phone, they should log in, and access the main page, which is a feed that displays the most relevant posts. From there, the user will have the possibility to access various functionalities. If they wish to associate with a new group, which can be represented by their class, their teacher, or a specific subject, they should specify the group code on the search bar and request acceptance (this procedure will ease the finding of groups and prevent unsolicited requests from outside students). In all cases, the student does not get an allowance in the desired group until their teacher approves it. After receiving a notification, the teacher can decide whether the student meets the criteria to join the group. If he/she does, the student gets accepted; otherwise, the request is declined. Followed by this approval or disapproval, the student can return to the initial page and choose if they want to participate in the class or proceed with other activities. If the latter option is chosen, the user can either open their evaluation tab, read their feed or Wiki page, or access the group they wish to interact with. In this section, they access the open threads, meaning that they can post and view content that is categorized by subject or topic. The posting of content by the user such as text accompanied by pictures, simple statuses, videos, or links to other websites, is accessible to all the members of the group in which the content was posted. The other users can read and comment on other posts and replicate human reactions with specific icons – agreement, disagreement, doubt, or surprise. This virtual interaction will later be useful for the in-class discussion of topics.

During the course of the class, the teacher will initiate the discussion on a specific topic, and the students will refer to the posts once made by the class on the application. An important remark is that the posted content, and consequently the in-class discussion, will have a fundament in the individual research conducted by each student on several sources of information. Whenever there are intentions of collaborating in the class discussion, the student will press on the participation feature, which will generate a notification on the teacher's side, and once it is appropriate, there will be given permission for the student's participation.

In the end, that should be stated whenever the teacher agrees that the topic has been sufficiently explored; there should be collectively elaborated a summary of what was discussed based on the application, which should include arguments, counterarguments and common ground that was reached. The summary is translated on a new thread that will look like a Wiki page, representing the connections that were established with the interaction of different nodes – different students with diverse points of view and sources and the moderation of teachers. This Wiki page will be made accessible throughout the academic year. The interaction of the students in the platform, meaning the posted content, comments, and later the inputs on the Wiki page, will be translated into important data insights. These insights will reveal how the student connected with different nodes and retained the knowledge and will help the teacher to proceed with the evaluation.

A new process is initiated when any topic is concluded and evaluated.

4.3. Model Implementation

The platform to assist the model can be built as a mobile application for smartphones. Thus, a new mobile application will be proposed within the constraints of a simplified conceptual framework. In this subchapter, there will be described the requirements for the mobile application, which can be divided into Functional and Non-Functional. Software requirements are conditions that need to be fulfilled in order to achieve an objective or to correspond to the constraints of system components.

The Android mobile application should be developed using Kotlin programming language, which is considered to be more efficient than other traditional languages, such as Java. Kotlin advantages are widely recognized, as it offers a flexible range of tools for android developers, less margin for errors, and more conciseness and safety (Bose et al., 2018). The User Interface (UI) design should be carried out with Jetpack Compose, which uses Kotlin code and is Android's most recent simplified toolkit (*Jetpack Compose UI App Development Toolkit - Android Developers*, n.d.).

The iOS version of the application will make use of Swift, a recent, intuitive, and powerful programming language. The language is open source, which contributes to a richer experience when developing the application. Swift has been proven to be fast and secure (Fojtik, 2020). As for the interface development kit for iOS applications, UIKit will be applied (*UIkit*, n.d.).

The table below presents a summary of the technologies to adopt in both operating systems:

Table 5 - Android and iOS specifications

	Android	**iOS**
Programming Language	Kotlin	Swift
UI Design toolkit	Jetpack Compose	UIKit

4.3.1. Functional Requirements

Functional requirements (FR) describe how the system will work and are set by users. Below, there will be presented the functional requirements of the mobile app:

- The software should allow the users to create profiles containing the following details: name, date of birth, school, class, and picture (optional). The sign-in should be supported by Two-Factor Authentication (2FA), a security technology that, by demanding two methods of user data authentication, ensures protection from unauthorized parties entering the system. The application should require the e-mail confirmation of the created account and the password chosen by the user. To log in, the user can only type his username and chosen password. Additionally, the users can log in using their school credentials;

- On the App, there should be permitted the creation of groups of users by class or professor. The acceptance of the students in the desired group depends on the approval of the respective professor;
- The software should allow the posting of content in several formats (pictures, videos, links, articles) on group threads about a certain subject previously searched on the internet by the students and have all the belonging group access to it. The storage of the content is made possible with the integration of the Firebase Realtime Database. This NoSQL cloud database allows users to access and synchronize data through several devices and does not require the use of servers. The content that users wish to post when they are not connected to the internet will be stored in the cache, and it will be automatically synchronized when they are online again (*Firebase Realtime Database | Store and Sync Data in Real Time*, n.d.);
- To allow users "virtual reactions" (like, dislike, doubt, surprise) that aim to replicate human reactions of agreement or disagreement and create higher engagement. The icons used in representing reactions can be found on the Font Awesome free pack for Jetpack Compose;
- To include a virtual button as a feature that, when pressed by the student, will notify the teacher about their willingness to verbally take part in the class discussion. This will ease the monitorization of participation;
- The tracking of the participation is conducted by the teacher in the App, who can assign a quantitative grade at the end of each student's input in the categories of speech coherence, relevance and ability to connect information nodes;
- The App should include a section where there will be posted a wrap-up of the group discussion, containing a conclusion that mixes students' inputs and common ground found by the constant search and contradiction of several nodes of information;
- The data generated by the App should be able to be extracted to a Learning Management System and provide helpful insights to evaluate the success of connections, revealing the different contributions provided by the students, as well as insights regarding participation, coherence, and interaction feedback. These data are retrieved from the commentary and posting features on the App.

4.3.2. Non-Functional Requirements

The non-functional requirements (NFR) definition has not gathered consensus in the literature. The authors (Parthasararthy, 2007) consider how the system should perform in terms of reliability, response time, performance, security, availability, scalability, and capacity. The NFRs responsiveness and usability were added as they were considered relevant for this study.

- **Reliability:** in case of failure, the system must rapidly restore its performance and involved data. A metric often used to evaluate a system's reliability is Mean Time To Failure (MTTF), which represents the average time that a part of the mobile application takes to break down. This number should be as small as possible;
- **Response Time:** the system must present a stable architecture to support diverse communications protocols, and there should be executed performance analysis in all software development lifecycle phases to ensure its efficiency (Bharadwaj & Gopalakrishnan Nair, 2009);
- **Performance:** the system should present an efficient performance, meaning a reduced processing time, even during high user peaks. The response time of the server is frequently measured with Time to First Byte (TTFB), having milliseconds as a unit of measure of the time it takes for a browser to receive its first byte. When opened by the user, the application should not take more than 5 seconds;
- **Security:** users should choose which personal data they wish to have visible to other users, except for their name and class. The system should guarantee the protection of other personal data and have data recovery procedures implemented (Bharadwaj & Gopalakrishnan Nair, 2009);
- **Availability:** the application should handle long periods of usage in normal usage conditions without degrading;
- **Scalability:** according to the author, scalability refers to "the ability to scale up to peak transaction loads." (Parthasararthy, 2007), meaning that when the volume of data of the users and their posted content increases, the system should be able to promptly handle it without crashing, which will be made possible through complex algorithms;
- **Capacity:** similar to the Scalability NFR, the mobile application should be able to sufficiently handle the high volume of data required by end users.
- **Responsiveness:** whenever there is an external input to the app, such as a call, or when the user temporarily exits the app, the same page the user was interacting with should be maintained when he wishes to return; The users should easily access the discussion section;
- **Usability:** due to its finality being academic purposes, the system's interface should be designed to be generally easy to use for both university students and professors.

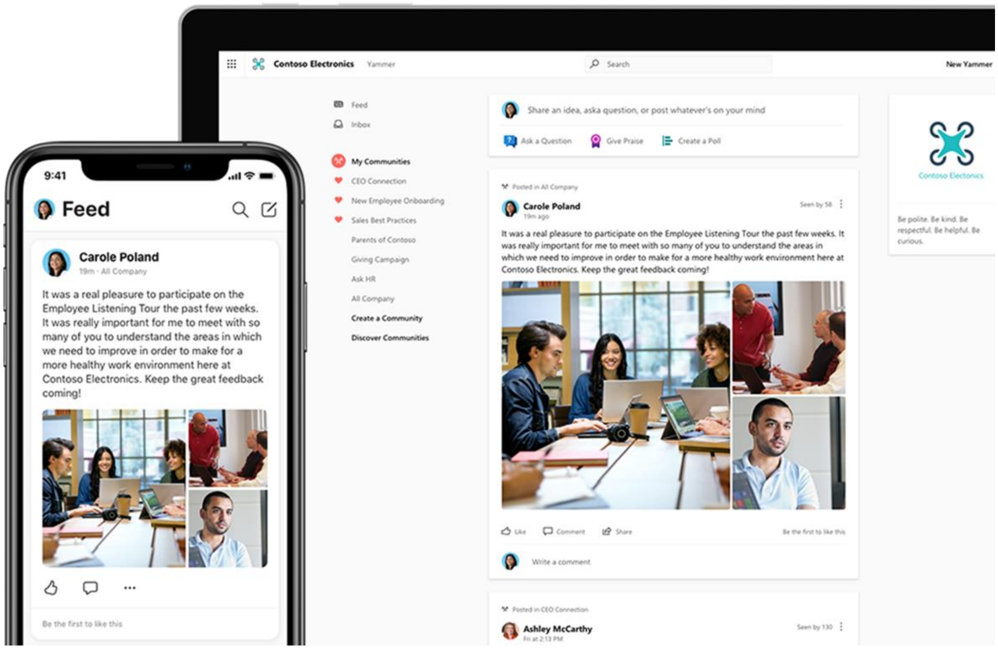
4.3.3. Platforms that Can be Used to Support the Requirements Implementation

The requirements presented above can settle on social media platforms that are currently offered in the market. These technological solutions are already being implemented in several enterprise and academic contexts.

The first example to be considered is **Yammer**, a Microsoft 365 integrated tool, described as an “enterprise closed social network” which is oftentimes applied in business contexts, aiming to promote user interaction and ease of communication. Launched in 2008 and acquired by Microsoft in 2012, Yammer counts with a manifold of functionalities (Scifleet, 2012).

On Yammer, each enterprise can be interpreted as a network of interconnected employees, where they are free to post textual or multimedia content, communicate via private messages, or take advantage of third-party applications installed externally. The group option on Yammer allows users to join different private or public channels of information, depending on the purpose they are serving, meaning either certain projects, teams, or meetings. The admin role on Yammer allows a pre-denominated person to assume control of certain permissions, users, or groups, acting like moderators of the platform. Furthermore, there are three different types of admins: network admins, that can modify Yammer’s configurations and manage users and groups; group admins that are responsible for operational moderation and customization of their groups, and finally, verified admins, that can do all of the above plus the management of security tasks. The content that is posted on Yammer is stored on the organization’s SharePoint and can be accessed from the platform itself or directly from the file’s location. This social network has been proven to contribute heavily to a richer experience for employees to share ideas and general information, solve complex problems, and team building (*Microsoft Yammer | Collaborate & Connect with the Yammer App*, n.d.). Although Yammer is widely used, and there are studies that point to the benefit of its use in a school context, it is still a platform that exclusively addresses the interaction of its users almost exclusively online (Munusamy et al., 2019). The image below exemplifies Yammer’s interface from the perspective of a computer and a smartphone.

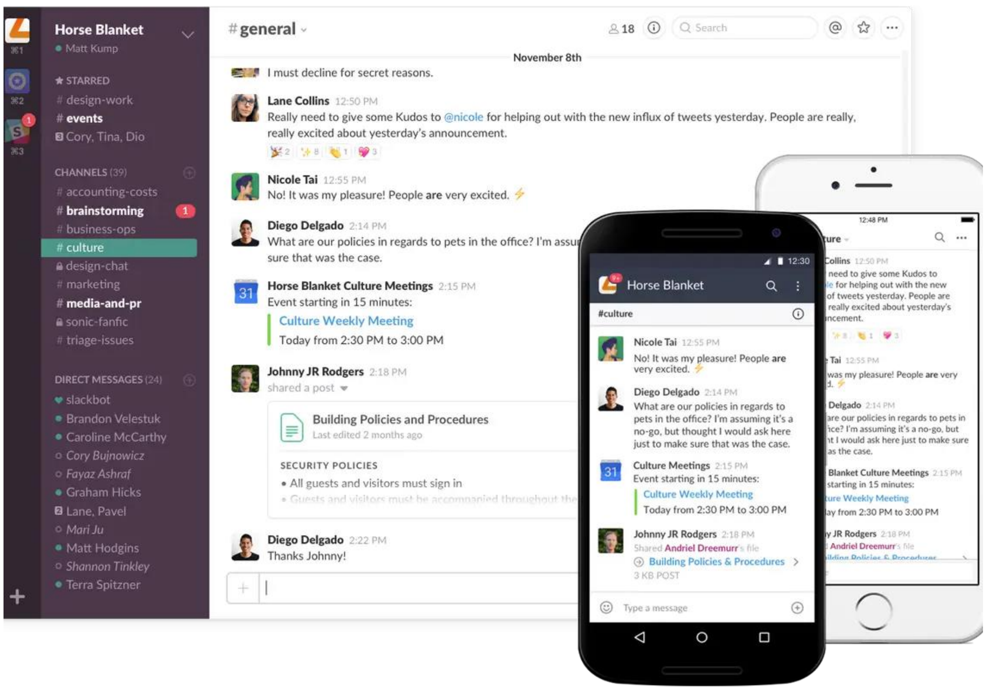
Illustrative figure 6 - User interaction using the Yammer social platform (Microsoft, n.d.)



The second example is **Slack**, which consists of an enterprise instant messaging platform that was launched in 2013 and acquired by Salesforce in 2021. Similar to Yammer, Slack allows its users to share files and messages in real-time within different channels – groups created according to specific needs, whether they are projects or teams. These can extend beyond the organization's employees and include suppliers or clients, creating a space of sharing and creating relationship value. Besides commenting and adding up to the posted content by other users, there is the option to react with an emoji to the post.

A study conducted by (Darvishi, 2020) described Slack as an easy-to-manage collaborative social network in an academic context. In the same study, students referred that the use of the platform boosted their collaboration with their peers as well as professors, thus, their ability to create meaningful connections. They highlighted as positive aspects the communication through private messages, followed by asynchronous channel messaging. Concerning drawbacks, the lack of human interaction in the study process was emphasized the most by the students. Other factors pointed to the dependency on other peers in obtaining replies to posts, the limitation of writing comments in text format, and the fear of lack of data privacy due to the integration of Slack with other technologies. Below, there is presented a suggestive picture of Slack's interface on both the desktop and mobile application versions.

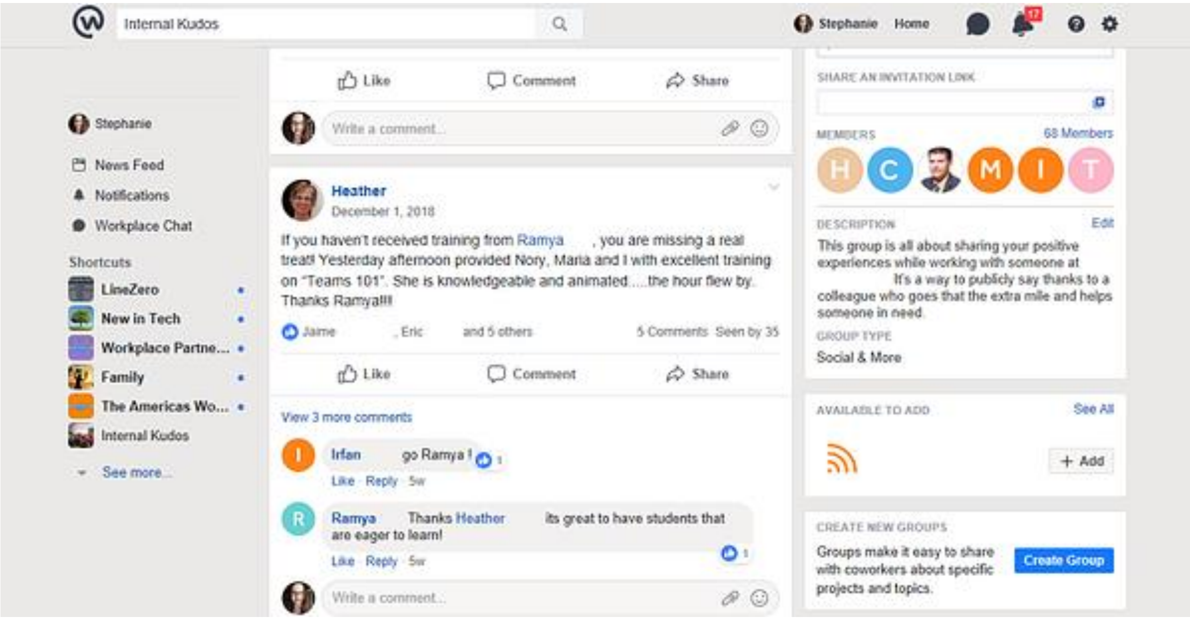
Illustrative figure 7 - User interaction using the Slack social platform (John, 2020)



Finally, the third appropriate example is **Workplace,** the enterprise social platform created in 2016 by Meta that goes beyond the chatting and posting of content and integrates video conferencing or even live broadcasting. It uses the same interface as Facebook, which makes the platform particularly attractive and easy to use. Like Facebook, Workplace uses AI to display a news feed sorted by the most relevant posts to each user and includes the option to create groups. One of the most acclaimed features is the Knowledge Library, where users can create, share, and access useful information, at any time and location, without the assistance of external IT solutions. Nevertheless, it is also possible to integrate this feature with other tools, such as SharePoint. The Insights feature acts like an overview of the activity within the Workplace platform, presenting relevant statistics on how the users are interacting or which topics are trending throughout the time. Safety Center is also a distinguished functionality for its purpose of creating emergency alerts for employees, usually in cases of natural disasters or public health outbreaks.

Although there are no specific studies that refer to the use of Workplace in academic settings, it is safe to assume that, like the previously mentioned social platforms, the impact is most likely to be positive. The authors (Oksa et al., 2021) included this platform in a study that revealed that social media as a work engagement and support tool could enhance employees' motivation in their tasks. The incorporation of these platforms into work helps users feel more connected with each other in a community sense, though it should not be used in a one-way form of posting and reading content.

Illustrative figure 8 - Workplace browser interface (Linezero, n.d.)



As it is clear that the use of these platforms alone will not help improve participation in the classroom and the consequent building of valuable connections, some adjustments will need to be implemented to accomplish the requirements listed in this paper. Thus, the goal is to benefit from the functionalities of the platforms in place on the market and adapt them to the principles of connectivism that suit this study. In this sense, the functionalities described above of sharing and interacting with the content posted on the network and in specified groups might contribute largely to the exchange of ideas among students. The platforms that include the data insight feature will allegedly contribute to a more precise tracking of each student's ability to connect, although it should be complemented with the teacher feedback, both online and in class discussions.

The part of the integration of a tool that allows the representation of the willingness to participate in the class will have to be later added to the platform, as well as a section that allows the user to access their evaluation. The private messaging feature should be disabled, as the goal is to foster communication with peers within the classroom and not online in a private context. The admin feature (Yammer) should also represent a "professor" profile, indicating a different status from the students, where this user will moderate content, insert evaluation data, and manage in-class participation in their classes. This role should be conceived by the academic services of the university. Finally, there should be integrated export APIs on the school's LMS, to extract insightful data from the platform.

5. RESULTS AND DISCUSSION

After having developed the framework, it is important to test its viability, which accounts for the Evaluation step in DSR. A total of six interviews will be completed with two students, two professors, one expert in education as well as one software engineer. These interviewees' opinions were considered relevant either due to their involvement in the educational process (students and professors), because they are experts on the subject of education (PhD student in Education), and due to their technical expertise (software engineering).

Table 6 - Interviwees' profiles

ID	Participant	Profile
P1	Master's Student	Currently enrolled in a Master's degree of Clinic Psychology
P2	Master's Student	Currently enrolled in a Master's degree in Business Law and Technology
P3	University Professor	Experienced university professor, PhD in Information Systems
P4	University Professor	Experienced university professor, PhD in Information Management
P5	Expert in Education	Teacher, currently enrolled in a PhD in Education
P6	Software Engineer	Experienced software engineer, Master in Informatics and Computer Engineering

With the conduction of these interviews, it is expected to accomplish a clearer perception of the impact that the framework would have in a real-case scenario. The questions asked and the respective responses of each of the four agents (student, professor, education expert, software engineer) will provide specific insights about the feasibility of the model, as well as other relevant aspects that can emerge throughout the dialogue. The table below compilates the interview questions.

Table 7 - Interviews script

Participant	Questions
Student	Q1. What do you think will be the impact of this framework on your learning?
	Q2. What do you think would be the main advantages and challenges when applying this framework at your university?
	Q3. What would you change in this framework?
Professor	Q4. What do you think of your role as a teacher in this framework?
	Q5. What do you think would be the main advantages and challenges when applying this framework at your university?
	Q6. What would you change in this framework?

Education Expert	Q7. Do you think this framework is a good representation of connectivist principles? Why/Why not?
	Q8. Do you think, short and long-term, both students and professors would benefit from this model?
Software Engineer	Q11. What is your view on the technical side of the implementation of this model?
	Q10. In your opinion, do the listed software requirements represent well what is intended in the platform?

The results will then be assessed and complemented with the literature review performed earlier in order to provide an insightful discussion on how to achieve the main objective of the research.

5.1. RESULTS

5.1.1. Student Interviews

- **Q1:** Both students mentioned that the traditional model in their universities is outdated. Both considered that their ability to learn was not being maximized when a professor was teaching students in a classroom and consequently, they were working on getting a passing grade on an exam. The new interaction with peers and the technology platform would make the learning process a more enriching experience based on the development of critical thinking. P1 mentioned that this model would contribute to his training as a more active member of society and professionally due to the autonomy in research and the fostering of discussion. P2 mentioned that this model could mean reduced pressure to achieve a certain grade in an exam, and that being able to force herself to learn continuously during the semester would bring her more benefits in the end;

- **Q2:** In terms of the advantages of applying this dynamic in a learning environment, both interviewees mentioned that, as students, it is an added value to be also assessed through interaction with peers, self-discipline in searching for information, and voluntary participation in class. P1 also pointed out several other factors, such as the greater focus on critical thinking, the ability to learn to manage large amounts of information, especially in this Information Age and the transition of the teacher's role to an attitude of moderating content and discussion, also guiding the independent study. P2 confessed that adopting this model would be a form of modernizing teaching at their university and contribute to greater computer literacy. It was perceived as a challenge by P1 that there might exist a disadvantage for students with greater difficulties in socialization, causing a possible retraction in participation. P2 has doubts about how to evaluate a student based on, among other things, the posts on the platform. This is because it can create dependence on this social network by being required that the students frequently interact online;

- **Q3:** P1 indicated that, in this framework, considering the mentioned disadvantage, it would be important to implement the possibility of talking in private messages with the other students. P2 pointed out the fact that the assessment focuses so much on the online component. She thinks it would be more important to focus on the discussion in the classroom.

5.1.2. Professors

- **Q4:** Both participants highlighted the importance of the role of the professor in the presented framework. P3 referred that oftentimes the success of the students is influenced by how the professor engages with the assembly, the empathy that is or is not created with the class, and the content to be discussed. P4 emphasized two key roles that the professor must fulfil: on the one hand, the instructor must be careful to prepare the classes, moderate the contents, evaluate what the students have researched, and how effectively they have retained the information. On the other hand, "there is the pedagogical part, where connectivism comes in. There, the professor must motivate and drive the students. Professors must confirm if the students have learned the contents and if they have fulfilled the objectives of the theory.";

  They shared common practices that resemble connectivism that they are already implementing in some of the courses they teach at university: P3 stated, "I use many of these things as a teacher. I make invitations to the students, I promote pitches, I open a PowerPoint, and we [the class] take stock of the situation, and I think about what was important in the given subject. Even in theoretical classes, I have already framed a theme, each student has a week to prepare this theme, and then the student makes a 5-minute pitch, then I take it and make a paste with the present theme." The same interlocutor defended that these practices do not work the same for different audiences, but it is generally benefic. P4 referred that she implements the pedagogical practice named Team Based Learning, where students have the possibility to create knowledge in groups about certain topics;

- **Q5:** The two professors agreed that learning collaboratively within a network, produces positive results for most students. They consider that with this framework, students would most likely feel motivated to engage with the class and benefit from an enriching experience by connecting with students with different opinions. P3 believes that active class participation in person, rather than online, creates more value: "in terms of learning, there is more involvement in person. At online settings, sometimes we don't hear certain comments." It was also mentioned that it is very important that the students are prepared for such participation beforehand. If the students are creating something together, i.e. a shared document, the memories created inside the classroom will be more valuable.

As perceived challenges, the two interlocutors mentioned that the lack of interest of a student could affect the course of the class. P4 stated that if the audience is too big, trying to initiate a class discussion where most of the students would want to participate would be difficult to manage. The same professor raised concerns about how more introverted students would appreciate and succeed in this framework – some students; she said, "are shyer and prefer more individualistic learning and not together.".

- **Q6:** As additional changes to this model, P3 proposed that the syllabus of the whole course is available for the students a priori, "as it can be helpful to the student because you know the content and you know if the topic interests you can motivate and meet them.". In line with what the interviewee had previously explained, she stated, "to carry out this dynamic; there would have to be smaller classes (e.g. in crowded lecture classes, [the framework] would not work), as the focus would be lost.". She added that the groups would have to preferentially be determined by individuals with different characteristics that complemented one another, as it would contribute to a richer experience for the professor and the students, eventually creating more value and knowledge. Finally, she considered that it was critical that the discussion moments were separated between knowledge-building and assessment because "under pressure, students will feel stressed and will not be able to retain knowledge as well.".

5.1.3. Education Expert

- **Q7:** P7 believed that the presented framework represents the connectivism principles well. She added that "it is important that this framework combines the technological part, which we can't escape from, with the in-person discussion of topics. The autonomy of the students in searching for information and connection with different students represents well the learning theory.".
- **Q8:** Regarding the perception of the effects of the application of the framework on students, the interlocutor commented that this would foster opinion sharing among students and help them become more open and accepting of others' opinions, in and outside the platform. As another benefit, she further referred to the fact that students would "learn how to prepare and write more structured arguments.".

  The educator additionally suggested that "as we cannot eliminate the traditional form of teaching, this framework should be implemented only occasionally, in a flexible form, as a complement to other types of classes.". She considered it important to educate the students on how to look for relevant information, from reliable sources, or it could become dangerous for society to be exposed to prejudicial sources. It is, therefore, crucial that students detain the maturity to know how to distinguish opinion from factual information. The interviewee highlighted the importance of not assessing participation, as it should be a learning process. She continued by saying that "there could be feedback and guidance from the professor, but we can't punish someone for not wanting to participate. However, the final result, i.e. the «Wiki page» built by all the class, should have a weight on the evaluation.". Finally, it was mentioned that it is crucial to consider the "student's prior learning and individual context", meaning that some students are not comfortable participating in class, and should not face pressure in this sense.

5.1.4. Software Engineer

- **Q9:** P6 argued that the implementation and maintenance of a platform that is "built-from-scratch" are highly costly, and therefore, the platforms existent in the market represent better solutions. Nevertheless, it was clarified that it is still expensive to obtain licenses for a large pool of users. The intervenient highlighted the difficulty in implementing these sorts of technological solutions at a large scale, as it would depend on the rector's approval, which is, oftentimes, quite a bureaucratic process. The intervenient also expressed concerns about the need for certain technical expertise from the professors and students to be able to take advantage of the platform, which is not always observable, even in a university context.

  P6 suggested that the Wiki page displays, exclusively to the professor, which part of the document corresponds to each student's authorship so the evaluation is fair and clear.

  Q10: P6 confirmed that the software requirements reflect, at a generic level, the functionality and technical aspects of the platform that support the model.

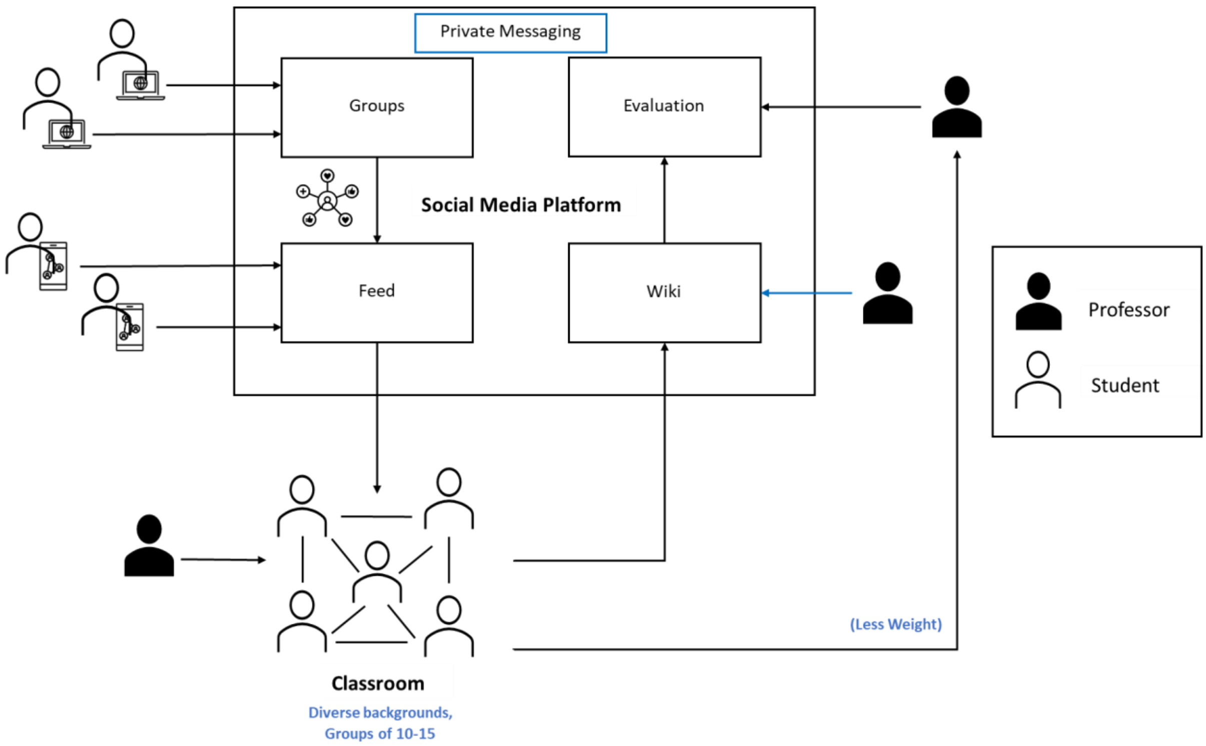
5.2. MODEL REFORMULATION

The feedback that was obtained during the evaluation phase of the artifact enabled the identification of possible deficiencies and eventual modifications that could be helpful in maximizing its benefits for both learners and instructors, although the adjustments are not very significant. As some of the external insights represented criticism towards the learning theory itself, which is not the scope of this research, not all mentioned negative aspects of the model were considered. In this regard, the inclusion of some of these observations could result in a deviation from the learning theory that aims to be reflected in this framework.

From the technical point of view, the integration of a chat feature into the platform has been referred to as a means to reduce pressure from communication within a group for more reserved students. Additionally, the inclusion of a software requirement that allows the user with a professor's profile to see which part of the text was edited by each student on the Wiki page has also proved to be an added value modification.

From the pedagogical point of view, smaller, more diverse groups were considered by the experts to allow for better management of the audience by the professor, and a richer interaction between the learners. Students' performance assessment should also be reconsidered in order to guarantee that less weight is given to the in-class discussion. Students should be able to interact with each other without being exclusively concerned with their evaluation. It was also reinforced, during the evaluation phase, that the professor should represent a stronger figure in the moderation of contents on the Wiki page in order to guarantee accuracy. The figure below represents the improved version of the model, with the new changes being represented in blue.

Illustrative figure 9 - Reformulated model for using Social Media Platforms to support a connectivism approach on campus



5.3. Discussion

This chapter will elaborate on points considered relevant in regard to the artifact and its evaluation. Thus, the subchapter aims to answer the main research question, "how to put connectivism into practice in a campus environment?".

The development of the framework was intended in light of the principles of connectivism and in-campus classes. In this sense, and considering the modernization of education, the suggested dynamics combined a hybrid form of learning, firstly starting with online research and interaction in digital platforms, followed by transferring the gathered knowledge to the campus classroom. Even though the proposition was to bring the ideals of connectivism into the physicality of a campus, it is inconvenient to ignore the role that e-learning has on most taught subjects. Therefore, part of the framework depends on the usage of digital platforms to accomplish its ultimate goal. Additionally, this research did not represent connectivism in its pure form but rather maximized the learning theory and turned the classroom dynamics into a connectivism-inspired one.

As connectivism strongly relies on self-study and autonomy is given to the learner in the exploration of meaning in a large pool of information resources, the initial part of the framework is for the student to effectively search independently about the topic that the professor has given. As retrieved from the interviews, the professor should provide a syllabus at the beginning of the semester with the intention of stimulating the students in class involvement. Whenever a new topic emerges, the professor must announce it to their students and provide the necessary guidelines, which will prepare the students for their self-study.

The exposition to external opinions proceeds when the learner is encouraged to share with their colleagues what he/she has searched about the subject, and simultaneously to read colleagues' posts. Such interaction will occur in a private social media platform, that must represent the software requirements listed in subchapters 4.3.1 and 4.3.2.. In terms of costs and effort, it is more advantageous for learning institutions to rely on solutions such as Yammer, Workplace or Slack, which offer desktop and mobile application versions. These social networks that are prevalent in the market were preferred over other popular ones, such as Twitter or Facebook, as they are typically suited to more formal scenarios, being usually incorporated in enterprise environments. Work-related social media shift their focus to efficient and structured communication, are able to align with the rigidness of the organization (the university, in this case), and its connections are based on roles, (for instance, professor and students). These work-oriented social networks are private, which is a factor of major importance, as we are dealing with student data (Song et al., 2019). Social media platforms are able to display a large pool of information and ease the interaction and structuring of the content. In this study's scenario, students will have the possibility to find different groups for each course they are enrolled in, which will facilitate their organization of contents. The fact that the students are asked to engage with each other on these platforms, and share the self-study they have performed prior to this, will most likely make them more prepared for the in-class debate they will face afterwards.

Once at campus classes, the group will gather in a classroom, and the professor may provide an introductory note which should be followed by a debate among the students. They presumably are more motivated and willing to expose their arguments by referring to what they have read on the digital platform. Thus, the feedback obtained from a professor during the evaluation phase has clarified that oftentimes, when students are required to take action in class, one of the reasons they may feel insecure is due to non-preparation. The fact that the students are aware that they are being evaluated based on their connection skills, meaning how they express themselves, correlate with what is stated by their peers, and prepare their arguments, can have two repercussions – either they will increase their effort in preparing for the in-class discussion, or they can focus more on the grade they will get than the knowledge itself. The second option is not favourable and can harm the learning success of students. As there is no learning model "one-size-fits-all", the viability of the proposed framework will always depend on individual characteristics. For instance, if a student is more reserved or insecure, he/she might not totally benefit from this framework, as they would rather study in an individualistic setting. Due to this factor, the grading method would have to be reassessed according to the class characteristics, course, professor preferences, or topic being taught. In line with this argument, some of the individuals that participated in the model evaluation assumed that there would have to exist a separation of discussion moments for evaluation, and discussion moments for knowledge sharing, in order to avoid the negative repercussions mentioned previously. However, they agreed that the final part of the dynamics, which links to a Wiki page consisting of a shared "document", or a place on the platform, destined for the class to co-elaborate on a wrap-up of what was learned, would represent a value-adding activity. This task of building knowledge as a group would be the moment where the connections that were formed during this process are ultimately accomplished. The fact that the document is developed at the end of the discussion will provide the students with a final synthesis of what was talked about previously, including different points of view, common ground and tasks performed in class. The information included in this section will be mediated by the professor.

Nevertheless, most of the interviewees referred that this framework would enhance critical spirit, ability to express opinions and structuring of arguments. The interviewed students confirmed that this learning model better prepares them for their future, in comparison to the current classes they are taking at their universities, as they believe that their voice can have an impact on the building of something greater. Additionally, it was mentioned that the fact that the students are compelled to study throughout the semester and are continuously evaluated is more advantageous to them than having few evaluation components. This is because they will be in contact with the learning content on a regular basis, and the building of knowledge will happen progressively.

As it is difficult to connect to different nodes in large environments, this framework would most likely produce a better result on smaller classes. This would improve the quality of the professor's tasks of moderating the discussions and evaluating students. The framework would also benefit from diversity in students' backgrounds and personalities. This could be put into practice by providing questionnaires to the students prior to forming the classes, which would form groups of students with different study majors/minors, different characteristics and forms of socializing. This practice is believed to result in a richer environment, adding value to the framework.

The role of the professors in such a model is critical – they must not only ensure that connectivism is being represented but that the content being learned is correct. The professor that acts within the constraints of this framework must motivate the students and ensure the correct functioning of the group. The platform must ensure that the wiki page section allows the visibility, of the professor, of what are the edits made by each student. Thus, the professor, alongside the text mining algorithms applied to the insight extraction of the interaction on the platform, will hold power to judge how successfully the connections were formed. It is, therefore, crucial that he/she detains knowledge about the learning theory, apart from the taught content.

6. CONCLUSIONS AND FUTURE WORK

It is possible to state that the model that has been presented and explored in this paper is a good example of how to apply connectivism in a physical campus context, although some rectifications to the typical showcase of the theory had to be made. Hence, the principles of connectivism, included in the Annexes chapter, were mostly achieved with the model:

- Principles 1, 4, 5 and 6 are achieved through the intense exposition of the individual to their colleagues' research, facing contradictory and complementary opinions in the platform, which are then deepened in the in-class discussion. The ability to form connections based on this is then completed at the end of these discussions, where the learners are asked to formulate a document that is where all the generated ideas are connected;
- Principles 2, 3 and 5 are accomplished with access to multiple information sources that only the internet can offer, allied with the interaction on the platform, where students can easily navigate through key points of their peer's own research; and,
- Principle 7 can relate to the professor's role in the model, although it will inevitably be more prominent in this model in comparison to typical connectivism contexts, where the student is completely autonomous in the choice of their curriculum since we are dealing with face-to-face classes. The instructor's presence is crucial in guaranteeing the currency and accuracy of what is being learned. Lastly, principle 8 might not be achieved because of this reason, as the model does not prioritize the possibility of students choosing their own curriculum. However, it can be partially attained with the initial autonomous research that is conceived for the learners.

The execution of this research was affected by various limitations. The fact that this model has not been implemented in a real scenario does not make a correct analysis of its possible impact. Therefore, the costs of implementation and maintenance were not considered for the conceptualization of the artifact. Time limitations and incompatible schedules made it difficult to conduct further interviews towards the evaluation of the model. Furthermore, the model's outcomes will always depend on the actors involved, as well as on the courses concerned.

In the future, there is still plenty to be explored in regard to the practical application of connectivism. Research can be done towards the application of connectivism on campus, but with a stronger focus on specific disciplines, that might require additional technology, and techniques. Given this, it may be relevant to investigate how to integrate technological trends, such as IoT with this new learning theory.

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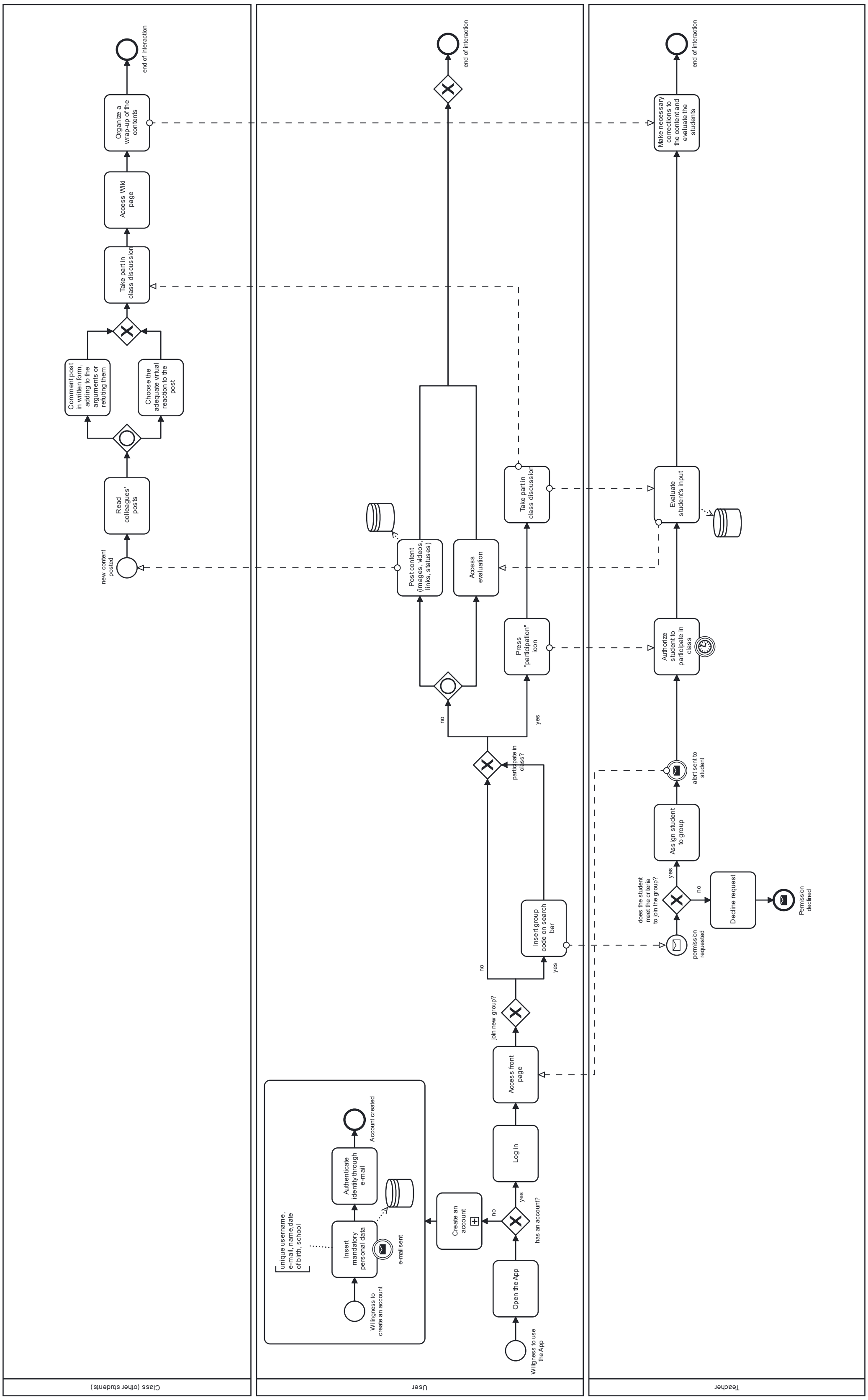
APPENDIX A – REPRESENTATION OF THE USER'S INTERACTION WITH THE PLATFORM



ANNEXES

PRINCIPLES OF THE CONNECTIVISM LEARNING THEORY, BY (SIEMENS, 2005):

1. Learning and knowledge rests in diversity of opinions.
2. Learning is a process of connecting specialized nodes or information sources.
3. Learning may reside in non-human appliances.
4. Capacity to know more is more critical than what is currently known
5. Nurturing and maintaining connections is needed to facilitate continual learning.
6. Ability to see connections between fields, ideas, and concepts is a core skill.
7. Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
8. Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision.