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# A fuzzy cognitive analysis on motivation, engagement, and participation: New trends and further ideas

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*In this paper, we explain how mathematics teaching with STEM undergraduate students has evolved over the past three years; it has moved from blending to fully distance learning during the pandemic. We were interested in how students reacted to changing environments from a cognitive point of view. Data were collected and analyzed with mixed methods. Then they were summarized through engagement, participation, and motivation, which described students' status, calculated through a fuzzy cognitive map. The results and experiences highlighted the positive and negative aspects of using technology in mathematics teaching. As a methodological implication of this research, we propose a teaching method that integrates moments of distance teaching with activities carried out in the presence. A mix of styles, a fluid flow of knowledge between the physical classroom and the virtual classroom. We call this Integrated Digital Learning.*

*Keywords: Distance learning, blended learning, STEM, mixed-method, fuzzy cognitive map.*

## Introduction and rationale

In mathematics education, Information and Communication Technologies (ICT) provides teachers with foundational tools and means to help teachers change teaching methods, support students in independent learning, and actively participate in discovering concepts and mathematics topics (Craig J. et al., 2020). Research on new specific forms of learning has emerged, and epistemological questions have been raised about how learning takes place and how knowledge emerges beyond the boundaries of traditional education systems. For many years, universities have been promoting distance learning courses for their students or blended courses, starting a real process of renewing teaching with technology (Drijvers, 2015). The pandemic of 2019 has speeded up this process by forcing schools and universities to organize teaching completely at a distance. This has caused a radical transformation of didactics. When there was a return to face-to-face education, the question arose as to whether the experience of fully distance teaching was positive and beneficial. Now we are wondering if it is worth continuing to use some of the positive elements of distance teaching. This work is part of research conducted by the authors since 2018 about the use of educational technologies, especially through a custom e-learning platform and innovative teaching methodologies in STEM (Science, Technology, Engineering, and Mathematics) courses, to support students in their learning process trying to improve engagement, motivation, and participation. Motivation (Lepper, 1998) is the driving force behind a student's willingness to learn, which can be influenced by expectations, goals, and emotions. It can be intrinsic (learning for its own sake), extrinsic (driven by external factors such as grades), or social (motivated by the desire to connect with others). Whereas engagement (Fredricks et al., 2004) is the amount of time and energy students devote to educationally sound activities, policies, and practices. Engagement can be active, passive, or disengaged and includes behavioral, cognitive, and emotional engagement. It is a crucial factor for educational

success. Finally participation (Bergmark et al., 2018) is the action of taking part in activities and projects taking into account emotions and social interactions. Participation fosters mutual learning, and collaboration is a helpful tool used within the participatory culture as a desired educational outcome. It is fundamental to engage students in both in-person and online courses and is one of the most important aspects of student learning. The definitions of engagement imply that it encompasses more than just participation, but also includes students' interactions, assignments, and forum activities. Thus, a teacher cannot assume a student's motivation solely based on their participation, and understanding the construct of engagement is crucial for developing a valid measure of student engagement. Armed with this knowledge, teachers can adapt their teaching methodologies accordingly and create an educational community that fosters emotional involvement and social activities, leading to a stronger learning experience for students. Our previous works highlighted the importance of using information technologies in the educational dialogue to prevent dropout by improving students' engagement, motivation, and participation linked to their status model described mainly through those parameters model. In particular, in 2016/17, a blended teaching model was tested with half-flipped teaching in the SCALE-UP learning environment. In 2017/18, blended teaching was tested using the Just in Time Teaching and Peer-Led Team Learning methodologies integrated with a social platform (Capone, 2022). In the academic year 2018/19, the experimentation used Augmented Reality to address some crucial topics of the mathematics course and evaluate student interaction and participation with Fuzzy Cognitive Maps (Capone & Lepore, 2020) as a systemic structure model for analyzing critical success factors of the learning system. Augmented Reality has overcome some students' difficulties with various calculus topics. In these years, studies were conducted on how a custom e-learning platform based on Situation Awareness theory and its feedback generation system influenced students' status described through their levels of engagement, motivation, and participation (Capone & Lepore, 2021) using a Fuzzy Cognitive Map. Furthermore, we wonder if engagement, motivation, and participation in mathematics class change with full distance learning extended for the second year in an emergency context (Covid-19 pandemic). Therefore, based on the previous analyses, the research question we address in this paper is: how has the status of the student, identified through the parameters of motivation, engagement, and participation, kept evolving in response to changes in the external context?

## **Conceptual framework**

The teacher's educational activities and the student's reactions are analyzed in the light of the theory of transformative pedagogy (Mezirow, 1997), trying to understand if the transformations in didactic can create new teaching-learning methods able to survive after the emergency period, or if they are only transient manifestations dictated by contingent needs and destined to decline. Fuzzy Cognitive Map (Kokar & Endsley, 2012) helps us analyze how the students' status, described through a custom map based on engagement, motivation, and participation, reacts to a changing environment and to our didactic actions.

### **The theory of transformative pedagogy**

Transformative Learning Theory, proposed by Mezirow (1997), suggests that learning can change an individual's understanding of themselves and the world around them. This type of learning, called

"perspective transformation," occurs in three dimensions: psychological, where one's understanding of themselves changes; convictional, where one's beliefs are revised; and behavioral, where lifestyle changes occur. According to Mezirow, this transformation often happens as a result of a significant life event or crisis, but it can also happen gradually over time. The transformative learning process involves reflecting on and critically examining one's assumptions and beliefs and actively making changes based on this self-reflection. It also includes considering the unique educational needs of the individual. In this paper, some educational elements of Distance Learning that could lead to a paradigm shift in educational teaching are analyzed, such as, for example, the use of a social platform in the learning curriculum, the use of a platform to manage some moments of university distance learning, and so on.

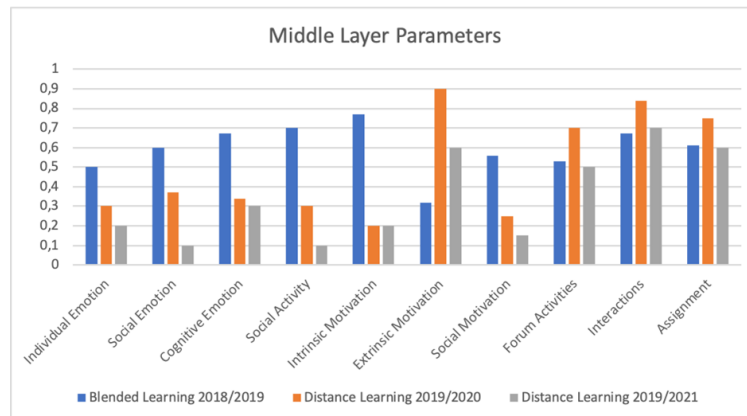
### **Fuzzy cognitive map**

A Fuzzy Cognitive Map (FCM), as introduced by Kosko (1986), is a symbolic representation based on a fuzzy graph useful for representing causal relationships. It can symbolically describe complex systems/environments, highlighting events, processes, and states. An FCM consists of an interconnection of nodes through weighted edges: a graph node is called a concept, and an edge is called weight. The edge allows for implementing a causal relationship between two concepts, and the weight represents the strength of the influence of the relationship, described with a fuzzy linguistic term (e.g., low, high, very high, etc.). A Fuzzy Cognitive Map is developed by integrating existing experience and knowledge related to a system. This can be achieved by using a group of experts to describe the structure and behaviour of the system under different conditions. FCM is one of the core points of our research. The Fuzzy Cognitive Map (FCM) proposed in this study is comprised of multiple layers. The lowest layer consists of concepts representing atomic variables that have a clear numerical correspondence with the observed phenomenon. Numerical values can be obtained through software data collection tools or assigned by a human operator based on observations. For example, to model the engagement level of a math student, a low-level concept could represent the number of completed assignments. The activation levels of these "leaf" concepts indicate their value, and changes to one variable can affect other FCM concepts based on their causal relationships. The middle layer includes nodes that make up the top-level concepts, such as motivation. Intermediate-level concepts contributing to the definition of motivation could include intrinsic, extrinsic, and social motivation. A detailed description can be found in Capone and Lepore (2020).

### **Teaching experiment**

The study was conducted with first-year engineering students attending the Calculus II course on 2018/19, 19/20, and 20/21. It involved two tutors in addition to the course lecturer. This work uses a mixed-methods methodology to integrate high-level extension studies (typical of the quantitative paradigm) and specific, in-depth studies (typical of the qualitative paradigm). The quantitative data include the students' interactions on the e-learning platform, the results of the tests, and a semi-structured questionnaire according to the Likert scale. In addition, the anonymously proposed questionnaire to students included open-ended questions to infer the student's motivational state through qualitative analysis. Finally, a Fuzzy Cognitive Map (FCM) was built from the qualitative and quantitative data to compute the students' engagement, motivation, and participation parameters.

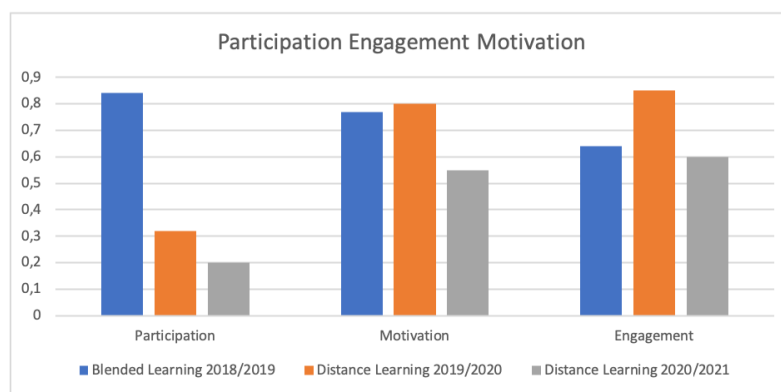
The quantitative approach suggests instructional, educational, and training strategies that might work under conditions. The qualitative approach provides information regarding why specific systems work. The data about students' engagement, motivation, and participation are analyzed by comparing the results of these parameters obtained in the academic years 2018/2019, 2019/2020, and 2020/2021. It should be noted that in the academic year 2018/2019 it has been used Blended Learning, whereas in the academic years 2019/2020 and 2020/2021, full Distance Learning was used. Figure 1 shows the average input values for the middle-layer FCM concepts, useful for calculating the values of the high-level layer in which the concepts of motivation engagement and participation are located.



**Figure 1: Middle layer results computed through FCM**

The three graphs show the comparison between the three groups of students into which the sample was divided: “Blended Learning 2018/2019” (represented in blue), students who attended classroom lessons and used the reference e-learning platform during the academic year 2018/2019, while in “Distance Learning 2019/2020” (shown in orange) there are students who have followed the course completely online during the academic year 2019/2020; lastly, in “Distance Learning 2020/2021” (shown in grey) there are students who have followed the course completely online during the academic year 2020/2021. The first three parameters reported, namely Individual Emotion, Social Emotion, and Cognitive Emotion, which refer to the emotional states of students (Peacefulness, Happiness, Satisfaction, Self-confidence, Admiration, Interest, Curiosity, Enthusiasm, Pay Attention, Discussion), highlight a situation of greater positivity in the 2018/2019 academic year in which teaching was of the blended type. The emotional state of the students in the academic year 2019/2020 was affected by the emergency caused by the pandemic. The drop in these parameters manifested by students in the 2019/2020 year is even stronger in the second year of distance learning. The Social Activity parameter, the result of the inference on Pay Attention and Discussion levels, plummeted from blended learning to the second year of distance learning, despite teachers' efforts to encourage social dialogue among students during class. The parameters related to motivation (Intrinsic Motivation, Extrinsic Motivation, and Social Motivation) show a huge difference between the three years. In fact, in the 2018/2019 academic year, students attended the course and activities offered by teachers because they were driven to enrich themselves and share this experience with colleagues. Whereas the students of the academic year 2019/2020 had an external constraint to follow the online course as the only way to obtain the attendance required to access the final exam. The situation was even worse in the 2020/2021 academic year, in which the motivation for being able to take the exam

was not enough to take the course. Confirming this index, few students attended the final exam: in the academic year 2018/2019, 66% of the students attended the first available exam. In the academic year 2019/2020, 67% of the first available exam, and in the academic year 2020/2021, 42% of the first available exam. Forum Activities, Interactions, and Assignments, or the parameters related to Engagement, show balanced levels over the three years. Having the e-learning platform as the only tool available to access the teaching material and to carry out the exercises, the students of the academic years 2019/2020 and 2020/2021 show a comparable level of interaction to the students of 2018/2019 where the use of the platform was an additional part, used to integrate with some extra activities what was done in the presence. The average levels of engagement, motivation, and participation are calculated through the execution of the FCM (as shown in Figure 2), which summarizes what is reported in the analysis of the data of the middle layer parameters.



**Figure 2: Participation, engagement, and motivation results computed through FCM**

Despite the difficulties and digital barriers of full distance learning, during the first year of the pandemic, it appears that students were motivated (even if extrinsically) to attend classes, engaged, and interacted with teachers through the e-learning platform. Distance learning was experienced as a moment of being together. During the second year of the pandemic, students seemed more unmotivated. Interest and participation in the activities offered on the e-learning platform seem to have decreased. During the first year of the pandemic (2019/2020), even the parameters of engagement and motivation, although modest, are higher than in the year 2018/2019. The same graph shows how all three parameters collapsed during the year 2020/2021. Furthermore, in the same years, studies were conducted on how the situation-aware e-learning platform and its feedback generation system influenced the students' Situation Awareness level. We do not report here the detailed analysis of the results obtained but we will just observe how the students' level of awareness also went down reaching its lowest during the second year of the pandemic. This confirms how the three concepts (engagement, motivation, and participation) chosen to describe the student's Situation Model are practically related to the student's level of awareness. In addition, beyond using FCM as quantitative analysis, data gathered by Likert scale questionnaires administered to students each year at the end of the course were used for comparative analysis. It emerges that in the year 2020–2021, 64% of students answered 4 or 5 on the Likert scale to the question of how frequently they confronted each other on the teaching activities of the course using digital tools; while in 2018–2019, 40% and in 2019–2020, 69.77%. Furthermore, 62,2% of the students stated that they had interacted on the e-learning platform forum either assiduously or very frequently (4 or 5 on the Likert scale) in 2020–

2021. This value is higher in 2019-2020 (92%). As they declared, the forum allowed them to recreate the study room environment, although virtual, to discuss the solution to the exercises proposed in class. In 2018–2019, however, only 25%. The quantitative data analyzed through the fuzzy cognitive map seem to be confirmed by the qualitative results that emerge from the analysis of the student's answers to the anonymous questionnaire given at the end of the course. Information was obtained regarding the parameters of participation, engagement, and motivation from the questionnaire sent to the students and the social dialogues between students and teachers on the e-learning system. The questions mainly concerned how students felt about learning activities and social discussion, how motivated they were to take classes and study, and their relationship with the e-learning platform. Since the authors conducted a detailed analysis in (2020) of the answers from the students in academic years 2018/2019 and 2019/2020, here are reported the most remarkable answers from 2020/2021 students. Regarding the motivation parameter, the following most common students' answers were extracted:

- Student1: After almost two years of distance learning, there seems to be no end to this situation. I feel very unmotivated, even to study.
- Student2: I often spend entire days on the computer. I get tired easily and often don't feel like attending classes in their entirety.

As can be seen from the words of students S1 and S2, students' confidence in returning to face-to-face teaching has plummeted. This has led to a significant drop in motivation compared to previous years. Whereas, regarding the participation parameter, the following most common students' answers were extracted:

- Student3: Not being able to study on-site and deal with the professor and other students in person made me sad. The lack of socialization with the rest of the group completely turned off my enthusiasm for studying.
- Student4: Participating in face-to-face classes makes learning much easier for me. I find it difficult to take classes at a distance because of too many distractions and the lack of my classmates' presence supporting me in my studies.
- Student5: It was challenging to take the course at a distance because of the loss of student-class-teacher interaction. Better future teaching could keep together in-person and distance modes.

The participation parameter is the one that has been affected the most. This emerges from the responses of students S3, S4, and S5 that confirm the data analyzed through the FCM. Student S5 emphasizes the link between the difficulty of taking the course and the lack of interaction with peers and the professor. What seems to be common to most of the students' answers, however, is the negative effect of this emergency on their emotional state. Finally, regarding the engagement parameter, the following relevant students' answers were reported:

- Student6: The professors do their best to enable us to follow the course profitably, providing us with supplementary materials easily available on the e-learning platform.
- Student7: The feedback on the platform has been very helpful in clarifying doubts, especially on more advanced topics.
- Student8: On the e-learning platform, we found all the material needed to take the exam, but I often didn't want to log on because I had already spent too many hours on the pc.

The words of students S6 and S7, also shared by other students, reveal how the platform allows, using in a structured way the considerable digital content, to support teaching both in terms of theoretical and practical aspects. Whereas, student S8 highlights an important aspect of such a long-standing emergency situation: although the platform was well-designed and helpful for the study, the emergency situation caused disengagement.

## **Discussion and conclusion**

From the mixed method analysis conducted, it can be seen that in the year 2020/2021, the use of technology to support teaching was less effective than in the previous two years. Students appear tired of experiencing education in isolation; the prolonged emergency has negatively affected the emotional status of students, who are easily distracted and have little motivation to attend class. From these two types of analysis, we gathered one of our research's most important practical implications: distance learning was less effective than in previous years. Despite the efforts of teachers to provide effective teaching (as confirmed by the students' answers), there was a lack of social interaction and confrontation between students and between teacher and student. The network community they tried to build did not fully meet the need for direct interaction. Knowledge sharing also occurs through the emotions that arise from social dynamics, motivation, and engagement. So, context played a key role. The anxieties, stress, and lack of leading a normal life emphasized by the absence of sociability and distance from their peers combined with an excessive cognitive load of online information have taken over the students' concentration, attention, and a clear head. They had to question their own perspectives of meaning. The transformation to which they had been forced by the disorienting dilemma of the pandemic was being consolidated through familiarization with new roles and new relationships. The return to "normality" plunged them into a new disorienting dilemma by having to reintegrate their lives based on the conditions imposed by the new perspective. This further disoriented them. Although the system and the didactic methodologies were objectively valid, they were not as effective as in the condition of normality and tranquillity, as seen in the 2018/2019 year. Furthermore, from the quantitative analysis conducted on the data from the questionnaires administered to students, two important aspects can be noted: 1) students tried to make up for the physical presence by constantly interacting on the e-learning platform forum; 2) state of mind of students influenced their studies. Some were emotionally and organizationally prepared for a "perspective transformation" process and thus could perceive the positive aspects of the pedagogical transformation, while others were not. This aligns with Mezirow's transformative pedagogy. Some students faced anxiety and frustration, impacting academic performance (psychological dimension). They struggled to adapt, abandoning traditional teaching patterns (convictional dimension). Lifestyle changes negatively affected learning (behavioral dimension). In contrast, successful individuals overcame fears, embraced the "new" and thrived with e-learning and personalized methodologies. To sum up, the main finding of this research is: technologies are a tool to support teaching action but cannot completely replace the social action of face-to-face teaching. Although teaching activities have been remodeled and technologies have been used adaptively to optimize education, cognitive processes have been influenced by external factors that have partly compromised the effectiveness of the educational activity. The authors hope that some aspects the students appreciate can be integrated with traditional face-to-face teaching. In the months of distance learning, we have learned a lot: many

new skills have been created, both soft skills, such as the ability to manage time and the organization of study from a distance, and hard skills, such as the use of technological tools. Difficulties aside, if, from this forced distance learning experience, we have probably learned to adopt new digital processes to simplify teaching and to be more empathetic towards its students, then we will not have spent these difficult times in vain. We believe that the school of the future, the one that will have left the pandemic behind, will be able to combine what has been learned during the pandemic period and integrate technology as a teaching aid in the best possible way.

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