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Maximizing learning in online courses using critical thinking, project-based learning, and flipped classroom approaches

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Abstract:

Introduction: In this article, we present our findings regarding the lessons learned by using critical thinking, project-based learning, and flipped classroom educational approaches in an online course. The course, "Systems Thinking," was delivered to 20 graduate students during the Covid pandemic, in the second semester of 2020. The students worked in project teams to create short videos that analyzed the dynamics present in different real-life systems. The objective is to determine the effects of combining critical thinking, project-based learning, and flipped classroom to maximize learning.

Methods: We followed a convergent parallel mixed-method approach. The quantitative data was collected through two multiple-choice tests (pre-test and a post-test). The qualitative data was collected from students' discussion forums and students' projects. We also collected data employing one questionnaire sent at the end of the course. The data was analyzed following a systemic approach.

Results: The course design led to the development of five interconnected dynamics that favored the learning. The flipped classroom made the synchronous meetings more effective. The way the synchronous meetings were conducted (using different learning tools, tests as extrinsic motivators, and praising the students' achievements) kept the students motivated to learn. The discussion forum fostered critical thinking and the project-based learning approach gave opportunities to the students to learn by doing.

Conclusions: The combination of critical thinking, project-based learning, and flipped classroom can be a very effective way of enhancing the learning experience in online courses.

Keywords: critical thinking, project-based learning, flipped classroom, systems thinking, learning

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INTRODUCTION

In this article, we discussed the lessons learned by delivering the course "Systems Thinking" online. The goal of this twelve-week graduate course was to develop the students' Systems Thinking skills. The system can be understood as a set of elements interrelated and interconnected forming a complex structure (Bossel, 2007; Senge, 2006). This structure

allows to accomplish certain purposes (Ford, 1999). For example, a school is a system: its elements are the teachers, the students, the school building, the classrooms, etc. The school has the purpose to give the students the opportunity to learn something. Systems thinking is the study of systems. Systems thinking skills are the abilities that someone has that allows to understand and model systems in order to represent their inner structures, to comprehend their evolution

and their interaction with other systems (Meadows, 2008; Senge, 2006). More than that, to predict patterns of behavior (change of the systems over time) and to comprehend the impacts that systems cause in their environments.

In addition, the course aimed to foster the students' comprehension of the mental models that lead to the creation of systems. We also aimed to teach the students how to model them by representing their internal structures and patterns of behavior. Our overall aim was to develop students' capacity to understand the unintended consequences created by systems, to think critically about the systemic impacts of human activities on earth, and to strategize about ways of improving the existing systems.

To achieve those goals, the course was designed following a combination of critical thinking activities, project-based learning, and flipped classroom approaches. Due to the Covid-19 epidemic, the course was delivered online through synchronous (2-hour online meetings, delivered on Saturday mornings) and asynchronous activities (self-learning activities completed during the week).

Theoretical review

Learning is a gradual process of building new knowledge on previous knowledge (Bransford et al., 2000; Council, 2004). Neuroscience studies have revealed that when we learn something, neurons connect each other through synaptic junctions, creating neural networks (Immordino-Yang & Fischer, 2010). These neural networks are distributed over several brain areas. The learning process involves connecting the new networks with networks that are already in place (Cross, 1999). The stronger the connections between the neural networks, the more long-lasting the learning (Arantes do Amaral & Fregni, 2021). Fregni (2019), points out that critical thinking helps to create these strong connections.

Critical thinking is a term used to cover a wide range of processes (Dwyer et al., 2011; Halpern, 2013). In education, critical thinking can be understood as the mental processes that students may follow in order to analyze concepts from different perspectives (Fregni, 2019, Arantes do Amaral & Fregni, 2021). Critical thinking should involve reflection (Cottrell, 2017; Ennis, 2011; Ennis, 1987) and interpretation (Facione, 1990) of the content that is presented and the facts that support them (Huitt, 1998). In addition, it may also involve the analysis and evaluation of arguments (Allegretti & Frederick, 1995; Dwyer, Hogan, & Stewart,

2012). Researchers also point out that critical thinking may involve evaluation of the trustworthiness and accuracy of the sources of information (Carlson, 1995; Chabeli, 2007) and identification of logical fallacies and contradictions (Kurfiss, 1988; Murray & Kujundzic, 2005). Researchers also add that evaluation of critical thinking activities should be accomplished by taking into account a set of criteria (Gini-Newman & Case, 2018; Paul & Binker, 1990).

Critical thinking is an active process (Kintsch, 2009) rather than a passive one. It occurs when someone is motivated to learn and tries to make sense of the information that is given by establishing links with the concepts that the student is familiar with (Cross, 1999). The motivation to learn is driven by extrinsic and intrinsic factors (Fregni, 2019). In an educational context, the extrinsic factors can be understood as external factors that motivate the students to learn, such as reward and punishment rules created by the teacher (Bear, Slaughter, Mantz & Farley-Ripple, 2017). Intrinsic motivation involves internal factors such as autonomy, purpose, and mastery (Fregni, 2019; Gillard et al., 2015). Autonomy can be understood as freedom of choice (Guay et al., 2001). Mastery is related to the desire to improve on the accomplishment of academic tasks (Harackiewicz & Elliot, 1993). Purpose has to do with the significance of the activity accomplished (Nordgren, 2013).

Project-based learning (PBL) is an educational approach that, when well accomplished, may foster critical thinking (Masek & Yamin, 2011; Yuan et al., 2008). In a typical PBL-centered course, the students work in groups to accomplish a real-life project (Larmer & Mergendoller, 2010). Real-life projects may give the students a sense of purpose (Arantes do Amaral, 2019; Jacoby, 2014), thus contributing to the increase of intrinsic motivation. In addition, PBL learning gives the students autonomy (Arantes do Amaral & Matsusaki, 2017; Stefanou et al., 2013) as they may choose the team members, the project theme, and the way the activities will be accomplished. Moreover, PBL usually includes mechanisms that favor extrinsic motivation, such as well-established deliverables and milestone and assessment rules (Bender, 2012; Larmer et al., 2015). In addition, in PBL-centered courses, the students learn by doing, therefore increasing their mastery. In short, PBL may increase both intrinsic and extrinsic motivation factors to learn (Arantes do Amaral & Frazão, 2016; Blumenfeld et al., 1991).

Researchers also point out that PBL promotes in-depth inquiry (Larmer et al., 2015) by stimulating

students to undertake independent research and self-regulated learning (English & Kitsantas, 2013). Moreover, it also encourages knowledge sharing (Uden & Page, 2008), by fostering the students to work collaboratively in teams and stimulating the students to ask questions. PBL may also promote project walkthroughs (Markham et al., 2003) that allow retrieval opportunities. Even the mistakes that students make during the completion of the project may provide learning opportunities (Bender, 2012). In-depth inquiry, knowledge sharing, retrieval of contents, and learning from mistakes are actions that enhance critical thinking (Fregni, 2019).

PBL-centered courses may work even better if the students review the content before the class and use the class time to clarify with the teachers the points that they did not understand (McDonald & Smith, 2013). The professor should therefore scaffold the learning environment activities by providing material (such as video lectures, articles, books, games) to maximize learning (Milman, 2012). This educational approach, which encourages the students to study prior to attending the class, is called a flipped classroom (Bergmann & Sams, 2012). Researchers point out the benefits of this approach: the students can learn at their own rhythm (Kurihara, 2016) and have the flexibility to view and review the material whenever they desire

(McDonald & Smith, 2013). However, this approach requires students to have access to technology at home (Schmidt & Ralph, 2016) and the self-discipline required to study (Akçayır & Akçayır, 2018). More than that, it may substantially increase the professor's workload (Reidsema et al., & Smith, 2017).

Researchers also point out that the combination of PBL and a flipped classroom may have the potential of improving learning (Hu et al., 2019; Mehta, 2020) by fostering collaboration and participation (Moreno-Ruiz et al., 2019). However, it seems that there is still a lack of information about how to maximize learning by combining both approaches and critical thinking. This research aims to answer this question.

METHODS

The design of the course

In this section, we detail the critical thinking, project-based learning, and flipped-classroom educational activities accomplished during the course (**Figure 1**).

The projects and their educational goals

The students worked on projects in teams of four on average. Each team had the goal of creating a short video exploring the systemic aspects of human activities --

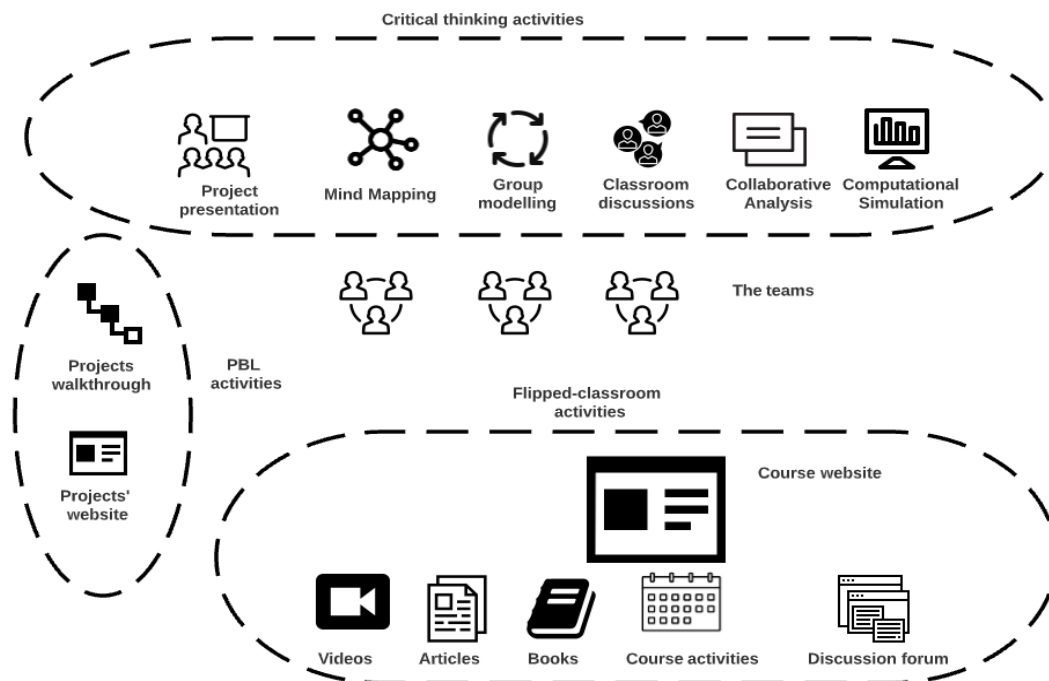


Figure 1. This figure represents the course design. Represents the critical thinking activities (project presentations, mind mapping, group modeling, collaborative analysis, and computational simulation) accomplished. It also represents the flipped classroom activities (the activities to be accomplished by the students before the class, such as reading articles and books, watching videos, performing course activities, and participating in a discussion forum). Finally, it also represents the project-based learning activities, such as projects' walkthroughs and the development of the projects' websites.

such as, for example, exploitation of renewable and non-renewable resources (**Appendix A**).

The project had the following educational goals:

- Provide the students the opportunity for learning by doing, by creating models that reveal the systemic structures responsible for real-life problems.
- Allow the opportunity for students to work together, researching and sharing knowledge.
- Allow the students to improve their mental models, by exploring the unintended consequences caused by systems.
- Encourage the students to perform a critical analysis of the subject of the research, by summarizing the project's main findings through a short video.
- Grant the students the opportunity to reflect together about their learning, using project walkthroughs.

Each team of students was also required to create a website for their projects. The website had the goals of:

- Fostering self-reflection about the learning processes and also registering the activities developed in the project, week by week.
- Promoting knowledge sharing between the teams, since each team could learn from the insights posted by the other teams.

The discussion forum

During the week, students were challenged to read articles or book chapters, watch videos (documentaries, interviews, class lessons) and accomplish project activities. Every week the professor posted one question regarding the course content of the week (such as the readings or the films that students were required to read and watch). The students were required to answer that question (or to respond to other students' questions) in a discussion forum. Sometimes the students were required to write down their answers. On other occasions, they were required to respond to the question by employing a short video. The discussion forum was created using the Google Groups tool.

The discussion forum had the following educational goals:

- Provide the students the opportunity to develop their critical thinking skills, by challenging them to present thoughtful answers to our questions.

- Allow the students to share experiences and examples, since the students came from different academic backgrounds.

The synchronous meetings

The synchronous meetings were the meetings between the professor and the students, making use of a web conference tool (Google Meets). The meetings were held on Saturdays and usually included three activities (**Appendix A**).

The first activity was a 20-minute multiple-choice test about the week's course content. After the students finished answering these questions, the professor discussed the answers to clarify issues.

The second activity was more practical, varying from week to week. Sometimes the professor challenged the students to create a model together, using simulation software such as VensimPle. On other occasions the professor discussed the students' interactions in the discussion forum, using mind-mapping activities and web-based tools such as LucidChart. At other times, the students were asked to perform a critical thinking activity, using tools such as Padlet. In other instances, the students made presentations regarding the status of their projects and received feedback from the professor.

The third activity was a short presentation by the professor offering guidance about the following week's activities and presenting the next question that should be answered in the following week in the discussion forum.

The meetings had the following goals:

- Provide extrinsic motivation to the students (through a multiple-choice test that aimed to measure the students' comprehension of the week's course content).
- Allow retrieval opportunities, by reviewing the main points of the study of the week and clarifying issues.
- Give guidance about the project activities.
- Promote modeling and critical thinking activities.
- Encourage the students to make connections between the new content and what they already know about it.

The course also had a website that provided access to all information (syllabus, articles, videos, books, discussion forum) that students would need to complete the course activities.

The professors' feedback

Every week the professor evaluated the students' participation in the discussion forum and the projects' activities. In the discussion forum, he read all the students' comments and then added his own, fostering critical reflection and participation and also clarifying issues.

He evaluated the projects' activities by visiting each projects' website and taking notes about their contents. After visiting the discussion forum and the projects' websites, he created a short video with his comments and sent it to the students. This way, he was able to keep all students informed about quality improvement actions that should be taken.

Research design

We followed a convergent parallel mixed-method approach. The quantitative and qualitative data was analyzed in an integral perspective: in combination, the data may complement each other, helping to understand the phenomenon under research (Creswell & Clark, 2017).

Participants

The twenty graduate students who were enrolled in this course participated in this research. The students had different backgrounds (**Table 1**).

Student background	Number of students
Veterinary	1
Pedagogy	3
Chemistry	1
Physics	2
Law	2
Sciences	1
Journalism	1
Civil Engineering	1
Nursing	1
Foreign languages (Spanish)	1
History	2
Mathematics	2
Psychology	2

Table 1. This table presents the information about the 20 students who attended the course: their field of study (academic undergraduate background) and the number of students of each field of study. We can see that we had students from 13 different fields of study, the maximum number of students of the same field was three (Pedagogy).

Data gathering procedures

Quantitative data was collected from test administered on the first day (pre-test) and the last day of class (post-test). As a post-test, the multiple-choice test was designed to verify if the students had comprehended the main theoretical concepts related to the discipline of systems thinking. The first three questions sought to verify if the students understood the concepts of causal relationships and feedback loops. The fourth question was designed to check if the students understood the concepts of stocks and flows. The fifth question sought to verify if the students understood the concept of mental models; the sixth to tenth questions were designed to check if the students understood the concepts of system structures and patterns of behavior. Qualitative data was collected in three different ways: 1) the professor's evaluation of the discussion forum 2) the professor's evaluation on learning what occurred during the projects' development and 3) the questionnaire sent to the students at the end of the course.

The discussion forum provided data that was used to evaluate if the students were developing critical thinking activities. The forum was evaluated under five criteria (**Appendix B**). We used a five-points Likert scale (Always, Very often, Sometimes, Rarely, Never) to evaluate the extent to which the students developed their critical thinking skills.

In other words, we evaluated the students' ability to analyze the concepts studied under different perspectives, if they were capable of reflecting and interpreting the content of the studies of the week, if they were able to evaluate the arguments, logical fallacies, and contradictions in the comments of their peers and if they were able to evaluate the trustworthiness and accuracy of the sources of the information presented by their peers.

The data from the projects was used by the professor to evaluate the students' learning, which included comprehension of the system dynamics modeling process in real-life situations, the usefulness of reflective learning records, and the relevance of the video created by the team. The project was evaluated under five criteria (**Appendix C**). We used a five-point Likert scale (Excellent, Good, Fair, Poor, Very poor) to evaluate to the extent that each project reflected the students' learning.

In other words, we wanted to quantify the learning by measuring how well the students developed their ability to create models that represent real-world problems, how well the students reflected on their

learning processes, and how well the final product of the projects (the videos that analyzed real-life systemic projects) reflected the students' learning.

The questionnaire (**Appendix D**) had the goal of asking students to evaluate how much they had learned from each component of the course: the discussion forum, the flipped classroom, the use of critical thinking tools, the studies of the week, the professor's feedback, the synchronous activities, and the modeling activities.

Data analysis procedures

The quantitative data was analyzed using descriptive statistic tools (such a box and whiskers plots). We analyzed the qualitative data from the questionnaires following the language processing method (Shiba & Walden, 2001; Yin, 2015). First, we compiled a database with all the students' comments. Then we reorganized the data into sentences, each sentence with one idea. After that, we grouped the correlated sentences into categories. In sequence, we grouped the related categories into broader clusters and created sentences that synthesized the main ideas of the clusters (Creswell & Creswell, 2017). We designated these sentences as Recurrent Themes (Bradley et al., 2007; Curry & Nunez-Smith, 2014). We did a systemic analysis (Arantes do Amaral, 2019) to understand the relationships between the quantitative and qualitative results. We used causal loop diagrams to represent the connections between the quantitative and qualitative data, facilitating the understanding of the dynamics that were present in the course (Littlejohns et al., 2018).

RESULTS

Quantitative data

	Mean	Median	IQR (Interquartile range)	Minimum	Maximum
Pre-test	6.0	6.0	2(5-7)	3	9
Post-test	8.4	8.0	1(8-9)	7	10

Table 2. This table presents the grades of the students in pre-test and post-test (tests applied at the beginning and the end of the course). It presents the mean (the average values of the grades), the median (the middle value of the grades, their central location) the interquartile range (the measure of dispersion, the difference between the 75% and 25% percentile), the maximum grade and the minimum grade.

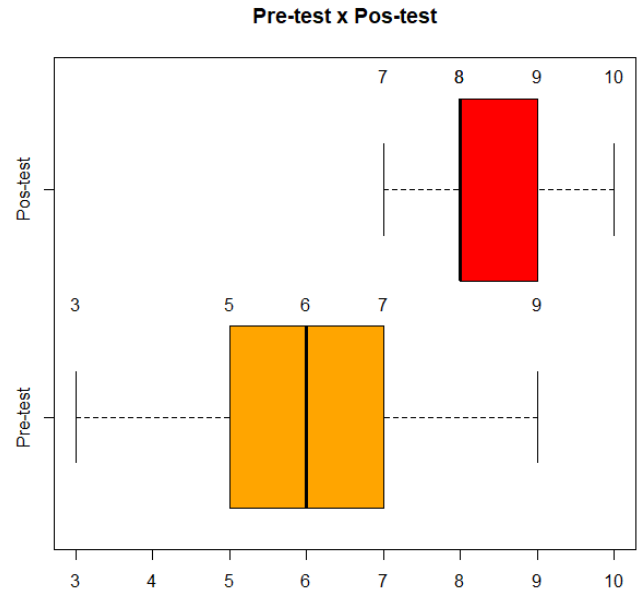


Figure 2. This figure (box and whisker plots) allows comparing the results of the pre-test and the post-test applied to the students. We can observe that the values of the median increased from 6 (pre-test) to 8 (pos-test). We can also see that the dispersion around the mean diminished from two, at pre-test (7-5=2) to one (9-8=1) in the post-test.

Qualitative data

Data related to the professor evaluation of the discussion forum

Critical thinking activities	Frequency
Criterion 01: Analysis of concepts under different perspectives	Always
Criterion 02: Reflection and interpretation of the content that is presented and the facts that support them.	Always
Criterion 03: Analysis and evaluation of arguments.	Very often
Criterion 04: identification of logical fallacies and contradictions	Sometimes
Criterion 05: evaluation of the trustworthiness and accuracy of the sources of information	Sometimes

Table 3. Evaluation of the frequency of critical thinking activities accomplished by the students in the discussion forum. Presents the five criteria used to evaluate the activities and the frequency of each criterion was observed (Always, Very Often, Sometimes, Rarely, Never). We can observe that the criterion 01 and 02 were always observed, criterion 3 was observed very often and criterion 4 and 5 were sometimes observed. More details about the evaluation forms we created can be found in Appendixes B and C.

Data related to the professor evaluation of the students' projects

	Criterion 01: the quality of the group modeling processes	Criterion 02: the quality of the reflective learning records	Criterion 03: quality of the product created (videos)
Project 01	Excellent	Excellent	Excellent
Project 02	Fair	Fair	Fair
Project 03	Fair	Fair	Fair
Project 04	Excellent	Excellent	Excellent
Project 05	Good	Good	Good
Project 06	Good	Good	Good

Table 4. This table presents the evaluation of the projects' artifacts (website and videos created by the students). We can see that we evaluated the six students' projects using three different criteria with five different degrees (excellent, good, fair, poor, very poor). More details about the criteria can be found in Appendixes B and C.

Data gathered from the questionnaire

Five recurrent themes (RT) emerged from the analysis of the answers to the questionnaire.

RT1: The diversity of the students facilitated the development of critical thinking activities

The data revealed that the students' diverse backgrounds allowed them to analyze each topic presented in the course from different angles and perspectives. Moreover, the diversity enriched the reflection and interpretation of the content, since the students connected the new knowledge with the knowledge they already had.

One student commented:

"Yes, the forum was a great place to exchange ideas. I learned a lot with the comments of my colleagues, especially from those whose backgrounds were different than mine. I liked the comments that encourage us to read other references and made connections between what we have studied and practical experiences..."

Another student added:

"I learned about critical thinking and argumentation by reading the comments of my

colleagues ...I learned to analyze the week's themes under different perspectives..."

RT2: The project allowed the students to develop their modeling skills and to share knowledge.

The students reported that the projects were fundamental to their learning process since the projects required the students to research real-life dynamics and model them. By doing that they learned how to represent the main dynamics present in their field of study. They also told us that they learned from each other during the grouping modeling activities.

One student commented:

"The project was amazing! It took time and effort, since we have to read articles, watch videos and update the project's website...it was a challenge, but it was worth it. I believe our group is very proud of what we have achieved and the evolution of our skills of building systemic maps."

Another student added:

"It was a rich and incredible experience, it involved a dealing with a diversity of ideas opinions and also with conflicts...working in a project involves multiple skills, from cognitive skills to attitudinal competences."

RT3: The participation in synchronous meetings gave the students better comprehension of the process of modeling.

The analysis of the data showed us the importance of the tests they took at the beginning of each meeting. The tests were effective ways of reviewing the material studied during the week. More than that, the usage of different learning tools (Padlet, Vensim, Google Forms, LucidChart Mind Mapping's package) made the meetings more interesting to the students.

One student stressed the importance of the tests:

"Another significant point in the meetings was the activities carried out at the beginning of the classes (the tests), as they served both as review the concepts and to clarify the questions."

One student reflected on the learning tools:

"The utilization of several digital resources and methodological strategies favored, in my view, the students' interaction and learning. We made systemic maps together, discussed questionnaires in real time, made presentations to each other, created collaborative panels... in short, we worked

together and made project activities, always mediated by the professor, who had always a very clear vision about the objective of the meetings.”

RT4: The professor’s feedback facilitated the learning.

The data showed that the students appreciated the feedback given by the professor, either in the synchronous meeting or by the videos sent to the students. These videos facilitated the understanding of the improvements that needed to be made on the models created by the groups and the content that should be posted on the project website.

One student pointed the importance of the feedbacks:

“Feedback was essential to our learning and for the improvement of our work (the project’s video, website and systemic maps). The professor’s feedback gave us guidance, showing us the right path to follow. The feedback stressed our successes and errors during the whole course duration. In addition, by giving feedback, the professor showed consideration and respect for our effort and knowledge-building process.”

Another student reflected on the feedback given through the videos:

“It worked really well. It was a quick resource with strong visual appeal. I think that written feedback about the systemic maps we created could be confusing and difficult to understand. The professor’s video facilitated to understand the points that would need to be improved or revised”.

RT5: The flipped classroom made the class time more effective

The analysis of the data let us understand the benefits of using a flipped classroom: the students were able to develop the majority of the activities proposed. Moreover, they acknowledge that studying before the class facilitated the learning process.

One student observed:

“Studying before the class favored the learning and optimized the class time for discussion. Many colleagues brought interesting reflections based on their studies of the week’s material and also based on their academic and professional background; the professor also helped leading the meetings.”

In addition to that, another student added:

“I think that studying the subject beforehand was very positive; we became well-prepared for the class. This allowed us to deepen the concepts during the class time. The professor also checked if the content was understood, and, if not, he clarified the issues.”

DISCUSSION

The data collected from the discussion forum (**Table 3**) revealed that students indeed utilized critical thinking during the projects. In addition, the RT1 revealed that diversity enhanced the critical thinking activities. These findings are in accordance with findings of other researchers (Fregni, 2019; Loes et al., 2012) who pointed out that class diversity may enhance critical thinking.

The data collected from the project (**Table 4**) showed that the PBL approach helped the students to develop their modeling skills: the quality of the product created through the projects also reflected that. This finding is aligned with the findings of other scholars (Milrad, 2002; Milrad, Spector, & Davidsen, 2003) who also reported the benefits of using PBL to develop students' modeling skills.

In addition, the data (**Table 4**, criterion 2) revealed that the students learned not only by doing but also by reflecting on the learning process itself. This finding is aligned with the findings of other scholars (Rolfe, 2014; Williams, 2001) who pointed out that critical reflection may improve learning.

The RT2 made it possible for us to know that the projects allowed the students to learn from each other, sharing knowledge. This is in accordance with the findings of other researchers (Page et al., 2009; Uden & Page, 2008), who also pointed that PBL fosters knowledge sharing.

The RT3 led us to understand the importance of getting the maximum advantage from the synchronous meetings, by using different tools to increase the attractiveness of the activities. More than that, it allowed us to figure out the importance of changing the learning tools from class to class, to get a hold of the students' curiosity and attention. This finding is aligned with the findings of other scholars (Chick et al., 2020; Tang et al., 2020) that reported the need of making the online class attractive.

The RT4 allowed us to understand the importance of giving guidance and feedback about the learning material and the project activities. Other researchers (Huang et al., 2020) also stressed the role of the

professor, to make the learning more effective in online courses settings.

The RT5 made it possible for us to comprehend that the flipped classroom can be very effective if delivered correctly. Other researchers (Singh & Arya, 2020) have come to similar conclusions. In addition to that, RT3 enabled us to know the importance of the tests accomplished in every meeting: they provided retrieval opportunities and also extrinsic motivation. Other researchers (Fregni, 2019) have pointed out the importance of keeping extrinsic motivation at an appropriate level to make the student participate in course activities.

The quantitative data (Table 2) revealed that the course provided learning opportunities: the results of the tests (Figure 2) showed that the mean of the grades increased from 6 to 8 and in the post-test: 50% of the students achieved grades between 8 and 9. More than that, the interquartile range diminished from the pre-test to the post-test, becoming narrower.

Systemic analysis

We created a causal loop diagram (Figure 3) to connect the quantitative and qualitative data, allowing us to have

a better understanding of the dynamics that drove the learning process.

Dynamic one: Fostering critical thinking

The first dynamic (Figure 3, feedback loop named "Benefits of Diversity") was triggered by challenging the students to participate in the discussion forum. The more the students participated, the more they analyzed the problems from different perspectives. In addition, the participation fostered their reflection about the course content, improved their skills in analysis and evaluation of arguments, and enhance their ability to identify fallacies and contradictions in the material studied and videos watched. This feedback loop led to the development of critical thinking skills, ultimately, fostering learning.

Dynamic two: Incentivizing learning by doing

The data discussed previously let us understand that the PBL approach was very effective: it allowed the students to put theory into practice, developing models for real life-problems. The PBL approach triggered the following dynamic (Figure 3, feedback loop named "Benefits of PBL"): the more the students participated in

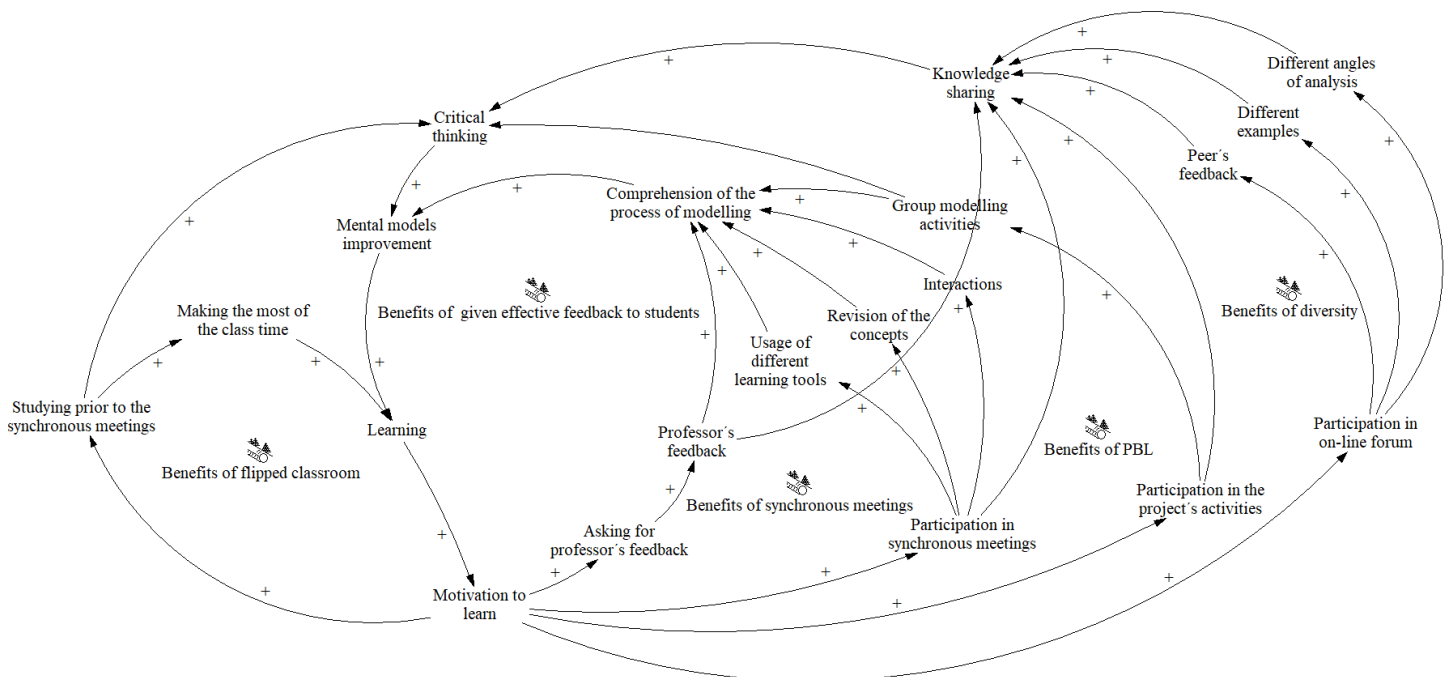


Figure 3. This figure is a causal loop diagram (a system dynamic modeling tool), that was used to represent the course's driving dynamics (the main feedback loops that drove the learning process). The feedback loops are identified by names. The figure shows five positive (reinforcing) feedback loops: "Benefits of flipped classroom", "Benefits of given effective feedback to students", "Benefits of synchronous meetings", "Benefits of PBL", "Benefits of diversity". The feedback loops allow to understand the connections between the educational strategies followed and the results achieved. This causal loop diagram facilitated our systemic analysis of the course.

the project's activities, the more they developed models together, sharing knowledge and developing their modeling skills. The development of the modeling skills contributed to the improvement of the learning.

Dynamic three: Making the virtual meetings meaningful

The previously analyzed data led us to understand that the way that we managed the synchronous meetings triggered the third dynamic (**Figure 3**, feedback loop named "Benefits of synchronous meetings"): the more the students participated in the meetings, the more they clarified issues, reviewed concepts and used different learning tools, therefore enhancing the learning experience.

Dynamic four: Flipping the classroom

The data analysis also revealed that the flipped classroom strategy made learning more effective. The more the students studied prior to the class, the more effective the synchronous meetings became, which also fostered the learning (**Figure 3**, feedback loop named "Benefits of flipped classroom").

Dynamic five: Keeping the students motivated

The professor's feedback contributed to the development of the students modeling skills, the development of critical thinking skills, and the increase of the effectiveness of the synchronous meetings, contributing therefore to the learning and to increase the students' motivation (**Figure 3**, feedback loop named "Benefits of given effective feedback to students").

CONCLUSIONS

We learned that it is important to invest time in designing courses carefully, defining the learning goals and the tools that will favor learning.

We also understood that the use of different learning tools in synchronous meetings was very effective: it triggered the students' curiosity and helped to keep their attention. The way we conducted the meetings (praising the students' efforts and achievements, clarifying the issues and fostering the discussion, respecting the different points of view, connecting the content with what they already knew) enhanced the learning. We may speculate that our actions triggered the students' intrinsic motivation to learn, because they were proud of the development of their modeling skills and their projects.

We also learned that the flipped classroom worked very well, and this success could be in part attributed to the quality of the videos and readings provided to the students. We asked the students to watch very interesting and real documentaries (such as the documentary "Social Dilemma" (Orlowski,2020)), a movie about social media addiction) and read meaningful articles. Both actions sparked the students' interest in the course.

We also learned that the discussion forum was a very important tool in fostering critical thinking. The diversity of the class made the forum very interesting; the students analyzed the subjects from different perspectives. The students participated intensively, sharing knowledge, making suggestions regarding articles, videos and websites. Sometimes we used these suggestions to improve the course content. The discussions were very rich: sometimes the students disagreed with each other. When this happened, we asked them to analyze each other's arguments, to identify fallacies and contradictions.

We have also learned that the professor's feedback, given to the students on video format, was very effective. The students appreciated feedback, paying close attention to the videos where we discuss the models and the project activities accomplished.

Conflict of Interest

The authors are members of the editorial team, therefore they excused themselves from the peer-review and editorial process.

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