IGARA: A Proposal for a Pedagogical Approach to Apply Educational Robotics through Collaborative Learning

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Abstract—This Research Full Paper presents **a proposal for a pedagogical approach to be applied to educational robotics on a virtual distance learning platform, to foster teaching and learning, knowledge sharing and interaction between teachers and students. Recent studies indicate that 21st century students can master different skills and competencies to achieve success in their education, among which we highlight collaborative learning and educational robotics. One of the resources which successfully employ collaborative activities is groupware, which is a virtual collaborative system that supports groups of people with common tasks or objectives and enables the management of group activities. Many research works show that educational robotics has become an important facilitating and motivating tool for students entering Computer-focused courses. Literature has shown that both tools are important for the application of a STEM approach and have led to good results in an educational environment. To analyse the learning perceptions of educational robotics in a collaborative environment, we have developed a pedagogical approach that relies on collaborative learning through a groupware called IGARA, developed on Moodle platform. Activities made available by the virtual environment were developed based on constructivist, interactionist principles, with task contextualization to enhance students' perception. In order to assess the functionality of such an approach, an exploratory study was carried out with a set of 14 students, divided into 3 groups, spatially distant due to Covid-19 pandemic safety measures. Preliminary results were very promising and groupware was well accepted by participants.**

Keywords— collaborative learning, groupware, educational robotics, programming

I. Introduction

Information and Communication Technologies (ICTs) have gained much more prominence in recent years and their importance has become evident in recent months. Due to the need for social isolation, ICTs took centre stage in the most diverse facets of daily life, especially in academic activities [1]. Given this scenario, the educational system has evolved to respond to changes, devising new ways of teaching and working. For 21st century students, it is important that master some skills and competencies, such as Creativity, Critical thinking, Collaboration and Communication (4Cs) [2].

For 21st century computing students, an essential skill is computer programming [3]. In order to cope with the pace of such a digital evolutionary process and ensure the next generations are inserted this new technological context, secondary, technical and higher learning programs have made computer programming available with greater frequency and accessibility to all layers of society [3,4]. However, when students are new to computing, they often find it difficult to understand the fundamentals of Computer Science [5], especially when they are beginners in the field of computer programming [6].

Robotics mastery is another important skill for 21st century students. [7]. In recent years, robotics has become very popular in the educational system, helping students exercise other 21st century skills, such as the 4Cs [2]. Recent studies show that Educational Robotics (ER) has become an important tool, both as a facilitator as well as a motivator for students entering the world of programming [8,9]. In addition to this, robotics fosters collaborative and motivational learning towards a STEM (Science, Technology, Engineering and Mathematics) approach [7,10].

Collaboration is a competency that allows us to work together to reach a goal [2]. Collaborative learning is an active learning process that promotes knowledge acquisition through group activities, in which members work together, collaborating to overcome challenges [11]. Students work to enhance team knowledge construction [12], which is an important competence for 21st century students.

Another application for robotics in the scope of an educational environment is the deployment of multi-agent systems as support tools. Over the last few decades these systems have been deployed as tutors to improve learning [13] or even to collecting and analysing the feelings of texts posted by students in the activities [14]. The multi-agent system can support cooperative learning, forming compatible groups and managing a classroom [15].

Therefore, we present a pedagogical proposal to apply Educational Robotics in a virtual distance learning platform, which will foster teaching and knowledge sharing through interaction between teachers and students. Among various activities to be performed, students will have access to programming both in simulations as well as in actual scenarios, arranged in distributed remote access laboratories.

In order to report on the research, this article is structured as follows: Section 2 presents theoretical foundations of collaborative learning, groupware and multi-agent systems; Section 3 presents the works related to this research; Section 4 describes the proposed pedagogical approach; Section 5 shows the methodology used in this proposal; Section 6 shows an exploratory study carried out to verify proposal feasibility; Section 7 exhibits outcomes and discussions about the experimental study and Section 8 shows the conclusions about this research.

II. Background

A. Collaborative Learning

Collaborative Learning is defined, in the context of schooling, as a situation in which two or more people working in groups, with shared objectives, help each other towards the construction of knowledge [16]. It is further added that though it is not a recent practice, it has increasingly been disseminated and used in recent years in the school environment because of its potential to make learning more dynamic.

We also emphasize that in collaborative learning, the student is responsible for his own learning and for the learning of other team members, building knowledge through group discussion and reflection. In this way, the learning achievements of a member are based on the success of others [17]. With such information exchanges, students achieve better results than studying individually, as collaboration induces interest and critical thinking.

B. Groupware

As ICTs and the use of the Internet became popular in the educational environment, collaborative learning has become more prominent and has acquired better resources to enhance functionalities. One of these resources is groupware, defined as software with a shared interface, which enables communication, collaboration and coordination of activities, providing support for groups of people with common tasks or objectives [18]. A groupware allows participants real-time (synchronous) or non-real-time (asynchronous) activities, which increases efficiency for geographically distant groups.

Despite the variety of names that virtual collaborative environments are given, we shall refer to the term groupware for this research [19]. A collaborative system, or groupware, requires a socio-technical perspective that represents the shift from individual thinking to thinking as a collaborative team [20].

C. Multi-agent Systems

In order to understand what Multi-Agent Systems are, one must first know that Intelligent Agents are computer programs that can perform tasks autonomously [21]. The name is a reference to its feature while acting within a particular environment; however, there is no consensus on a defining word so far, so they may be referred to as softbots, knowbots, taskbots, among other definitions.

In more complex systems there can be several agents performing, forming a community. Thus, a software in which several agents act in problems resolution as a community is called a Multi-agent system [15]. Multi-agent systems can act in a cooperative or competitive way, and they may or may not share obtained knowledge [21].

III. Related Works

The work carried out by Jawawi et al. [22], which pursued a more effective way of teaching and learning programming through a framework adapted from Problem-Based and Object-Oriented Learning (POPBL - Project-Oriented Problem-Based Learning), provided important bases for this research. The RoboKar was used for line-following robot activities. In addition to Problem-Based Learning, the said research states that they applied Collaborative, Project-Based and Design-Based Learning. As significant results, they highlighted that the framework contributed to students' better learning the introduction to programming. They also realized that students cooperated, when necessary, to solve proposed problems.

This work was also based on a research done by Almeida et al. [23] who provided a theoretical basis for this paper. A robotics and programming laboratory was equipped with multi-agent support systems to stimulate students' programming skills using Educational Robotics. The laboratory allowed for remote learning and users located at a geographic distance were able to practice programming on Lego Mindstorms robots. The reported outcome was an increase in motivation generated in students to continue learning how to program and to use robotics.

A research carried out by Ghazal et al. [24] proposed an educational platform to improve methods of teaching programming and robotics skills. The platform consists of components controlled by a friendly visual programming language which and can be handled both by beginners as well as by advanced users through a mobile application. Collaborative Learning and Problem-Based Learning were used to solve practical experimental activities. The students were able to improve their understanding of concepts and mechanisms by receiving feedback from electronic modules integrated to the robotic platform.

The development of virtual laboratories for teaching Industrial Robotics programming was the focus of the research carried out by Abreu et al. [25]. A combination of an Industrial simulation software named RobotStudio and theoretical concepts allowed students to develop programming and industrial robots manipulation skills. Simulators made it possible to test robotic cells without risk to students, apart from motivating them to apply their knowledge later on to actual robots and consolidate their learning.

The aforementioned works guide this research, aiming to deepen the knowledge presented by the aforementioned authors.

IV. IGARA PROPOSAL

IGARA is a groupware for Learning Educational Robotics created on Moodle platform, i.e., a collaborative software run within a virtual environment to provide support for work among geographically distant groups, enabling communication, collaboration, information sharing and Robotics learning.

The name IGARA has an indigenous origin and describes a simple canoe, carved from a log. Due to its simplicity, it provides natives a good means for navigating rivers and streams. Similarly, the IGARA approach aims to reach even the most distant locations, providing a simple and efficient way of learning robotics.

A central element of its architecture is the virtual environment where teachers, students and coordinators information are stored. The groupware also contains activities and challenges to students, aiming to promote collaborative learning. Activities provided by the virtual environment are based on constructivist [26] and interactionist [27] principles, with contextualization of tasks, to improve students' perception.

The coordinator designs activities, manages the registration of teachers and students and maintains the proper functioning of the groupware. The role of the coordinator is that of an observer whose contact with students is limited only to sending messages about the environment and clarifying doubts about the performance of the activities. Teachers play a key role in this method for they are the ones who are in direct contact with the students. They organize and coordinate groups, and assist them to better understand topics. However, the Teacher will not help them solve a problem. In a collaborative environment, the teacher is no longer the sole holder of knowledge, but becomes an advisor, recommending ways and means that will lead students towards knowledge.

Students are the focus of this research. They are organized in groups of a maximum of 5 people, who must carry out all activities and challenges in a collaborative way, through the virtual learning environment. Students choose a leader, who will be responsible for reporting their doubts to their teacher. The leading student is also responsible for dividing tasks so that everyone participates collaboratively.

Intelligent agents are equipped to perform several important tasks within the educational environment and, for such feature, we deployed a few in this approach. We have an agent to answer questions about specific subjects related to the content presented. This makes learning more dynamic as sometimes students may access the groupware at a time when the teacher is absent and an agent can assist them via a real-time chat.

We also have an agent to guide teachers through elaboration of activities and a second one to monitor students' performance, so that teachers can verify their learning, or even detect those who are prone to dropping out. Another agent is able to suggest didactic material according to the students' learning profiles while a different one assigns practical activities. All of these computational entities are gathered in an agents' community and are interconnected as well as able to exchange information between them. In IGARA, an extensible approach is used, i.e., it is possible to include new agents according to the system needs, aiming at improving the process.

Experiences and knowledge exchanged during intervention are essential for knowledge construction and for group success. These are striking features of collaborative learning. The environment allows not only learning, but also social, cultural and emotional development. Thus, everyone contributes to mutual knowledge construction. This architecture is represented in Fig. 1.

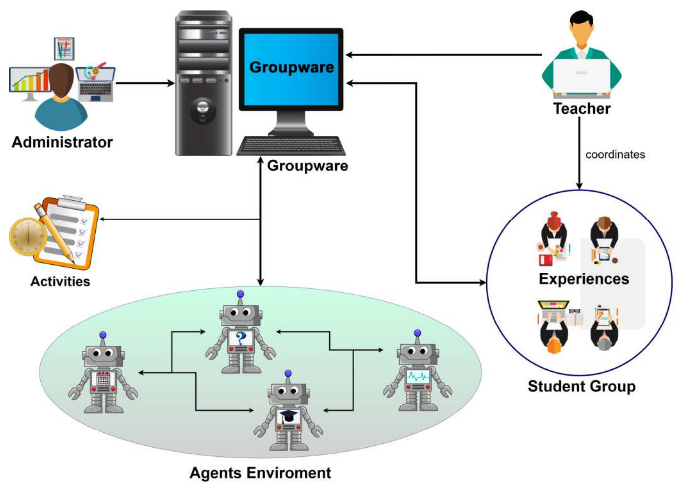

Fig. 1. IGARA's Architecture.

V. METHODOLOGY

This proposal employs a qualitative approach, as it analyses a problem without having to apply precise statistical methods, being more concerned with process than product [28]. It also has an exploratory, descriptive and investigative character. It was divided into 4 phases that are described in Figure 2.

Fig. 2. Methodology phases.

A. Planning Actions

This phase is characterized by planning all actions to be taken. A schedule with activities sequence must be drawn up and the teaching materials collected to be used by students. Materials can be hypertexts or videos and must be adapted to meet student's level. When suitable materials are not found, objects must be built to meet such needs.

B. Intervention

In this phase, one of the most important actions in this approach takes place, which is the intervention with students, which must be screened and divided into groups. The groupware is then designed and launched into operation together with all teaching materials and elaborated activities.

Students and teachers are duly registered and then start to use the virtual environment to access didactic materials and carry out the assigned activities. Participants are encouraged to solve all tasks collaboratively together with other members in the group. Exchanging messages through chats, forums and other collaboration tools available in the groupware are also encouraged.

Multi-agent systems provide all support through chats, recording all activities completed, suggesting extra support materials for specific content, analysing participants' behaviour through logs and also scheduling activities with the teacher. The teacher plays a fundamental role, because in addition to organizing groups, he collaborates with learning by answering questions and monitoring students' didactic performance.

C. Data Collection

Open and closed questionnaires can be applied before and after the intervention phase to capture participants' opinions. Other data collection tools that can be used are recorded interviews and observations, done throughout the entire research but, mainly during the intervention phase.

D. Results Analysis

In this phase, all collected research materials must be gathered and tabulated, for analysis and discussion of the results.

VI. Exploratory Study

In order to assess the functioning of our proposal, an exploratory study was carried out as it may be considered "the first stage in a much longer research process" [29]. Initially, the main objective was to test groupware functionality, as well to observe the collaborative interactions between participating students. Thus, for this initial study, multi-agent systems are not in use, however, they will be in later stages of this research.

To this end, preliminarily, this approach was programmed to contemplate the 1st and 2nd year students of High School in Computer at the Federal Institute of Amazonas, Campus Itacoatiara. The choice of a preliminary target audience was due to all selected students having subjects related to Robotics and Electronics in their curriculum, and those actions are of institutional interest, due to the high rate of failure in the referred subjects, a topic that is always central in discussions at the bimonthly pedagogical meetings. The survey was designed to be carried out in one week, but was carried out in two weeks due to problems with Internet access and other difficulties encountered. All activities were carried out in July 2020.

Fifteen students were selected to participate in this research, but one student had to be absent during the process. Thus, 14 students participated in this study and were observed and monitored during study phases, characterizing an action research [20]. The actions took place in conjunction with the monitoring of the school's teachers. Students used the virtual environment from home, accessing it using smartphones and computers.

The groupware developed was called IGARA for better identification and was available for full-time remote access to all students and teachers who participated in the project considering the availability and geographic location of participants. It contained pedagogical materials, robotics simulators, rooms for activities purposes and forums, to allow students to share ideas and ask questions. Regarding synchronous messages, participants decided that they would use a common smartphone application, especially because not all participants could keep IGARA on-screen at all times. As for asynchronous messaging, the Chat tool in the virtual environment was used and was monitored by the teacher and the coordinator.

Activities at IGARA for the initial stage of this research were comprised of four distinct phases, aiming at gradual knowledge construction and collaborative work, the main target of this work. The phases consisted of Reality Identification, Group Formation, Activity Development and Results.

The first phase was to learn about the characteristics of participating students and of the collaborating teacher. An initial questionnaire was applied to students and another one to the teacher. Participants learned about activities through synchronous messages sent by the teacher.

In the second phase, the groups were created under the teacher's guidance. 3 groups were created – 2 groups with 5 students and 1 with 4 students. Then, there was a virtual meeting with participants where each group chose a leader to help when tasks were executed together with other team members.

During the third phase, students were introduced to the functioning of IGARA, its structure and to the materials made available to them. Students had access to hypertexts and videos to acquire theoretical knowledge. The Second part was divided into 2 sections: Introduction to Robotics and Fundamentals of Electronics. After reading hypertexts and watching videos, students performed an activity creating a Forum. Then each group member exposed the ideas obtained through the material made available. The topic presented was a comparison between the Lego MindStorm robotic applications and the Arduino board.

As for Fundamentals of Electronics, once they understood the didactic material, students had access to a Tinkercad simulator and were able to practice the concepts learned in a simple and efficient manner, aiming at building circuits in a safe and realistic means. The proposed activity was a collaborative construction of a simple circuit in a simulator, involving a protoboard, resistors, LEDs and a 9V battery.

The third phase consisted of an experiment evaluating and measuring the knowledge acquired collaboratively. Final Questionnaires were prepared and applied to students as well as the teacher, upon which they were able to evaluate the methodology, the proposed activities, the IGARA groupware and express their opinions on points to improve and research's successes.

Steps described and used in this exploratory study can be seen in Figure 3.

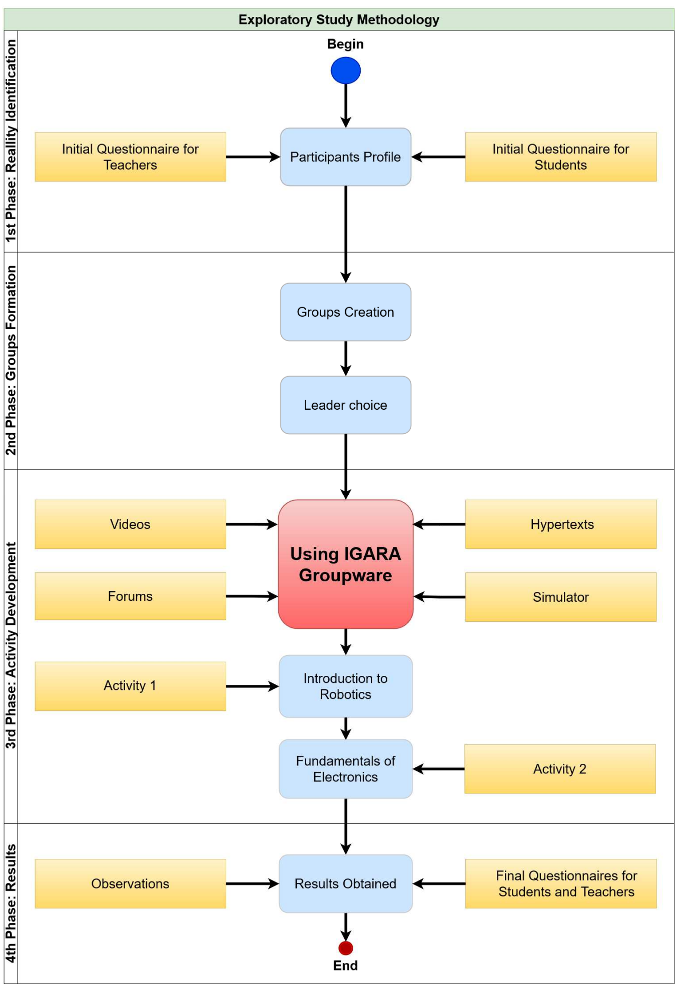

Fig. 3. Exploratory Study Methodology.

VII. Results and Discussions

A. *Initial Questionnaire for Students*

The objective of the initial questionnaire was to get to know the participants and note their interest in the field of study. Through this instrument, we obtained that age group was 15.7 years in average, consisting of 8 women and 6 men. Out of 14 students, 4 had already used Lego MindStorm robotics kit, i.e., they already had previous knowledge of Educational Robotics. Other questions are shown in Table 1.

TABLE I. Initial Questionnaire Summary Applied to Students.

How do you rate...	On a scale of 1 to 5, considering 1 as "**None**" and 5 as "**Quite**", choose the option that best represents your opinion.				
	Options (%)				
	1	**2**	**3**	**4**	**5**
1. Your knowledge of Robotics	57.2	21.5	7.1	7.1	7.1
2. Your degree of interest in Robotics.	0.0	7.1	21.5	42.9	28.5
3. Robotics Relevance in your daily life	14.2	28.5	21.5	14.3	21.5
4. Your ability for team work	0.0	21.5	28.5	21.5	28.5
5. The importance of Collaborative learning	0.0	14.3	14.3	42.9	28.5
6. How often do you study in groups	7.1	21.5	28.6	28.6	14.2
7. How much do you usually learn studying in groups	7.1	7.1	28.6	35.7	21.5
8. How much do you usually learn alone	14.2	14.2	21.5	21.5	28.6

The obtained results demonstrate that the vast majority in the group had no initial knowledge of Robotics, though there was a high interest in the area despite the relevance of this topic was quite controversial in the group. We also realized that most individuals were able to work in groups and considered collaborative learning important. Regarding the practice of group learning, though not unanimously, students answered they could study in groups a mean number of times. Although many reported that they usually learned well in groups, the vast majority usually learned more on their own.

B. *Teacher Questionnaire*

Getting to know the collaborating teacher better and his knowledge on the topic of this research was the Initial objective of the Questionnaire for Teachers. The Educator has a degree in Computer Science and works mainly with subjects such as Networks, Information Security and Web Programming.

About his knowledge of Robotics, the teacher stated he had a fair knowledge of the subject and that he was quite interested. He also reported having good knowledge and experience with collaborative work, however, he had only average knowledge and little experience with groupware. He also stated that he had a lot of knowledge about Interdisciplinarity, but little experience in practical applications in the work environment. The teacher described that he had not used robotics kits in class and was hopeful that the project would interest students, driving them to seek more knowledge and that they would be willing to put them into practice.

C. Students Final Questionnaire: IGARA's Evaluation

A Final Questionnaire was prepared with 11 questions, with the value "1" representing the worst case, "3" an average case and the value "5" the best case. Figure 4 shows the answers to the question of how much groupware had stimulated students' ability to study in groups.

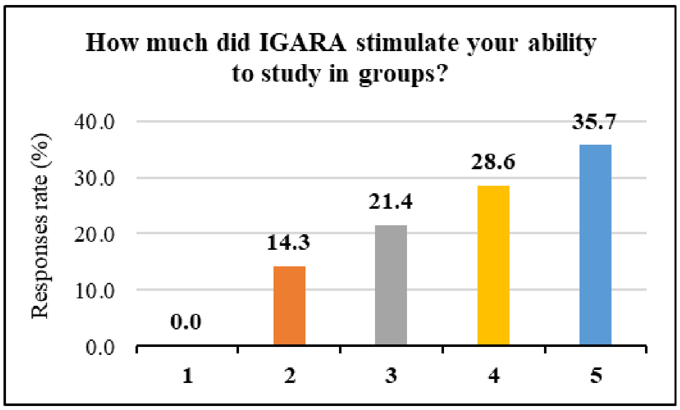

Fig. 4. Stimulating study in groups by IGARA groupware.

We noticed that there was a positive perception from students on this issue since the best cases had added up to more than half of students' answers. Since the beginning of this research, group activities had always been stimulated and when we compare Question 6 in Table 1, referring to the Initial Questionnaire, we realized that not everyone was used to studying in groups. This demonstrates an improvement in students' perception of group work. Figure 5 shows how much group learning has improved.

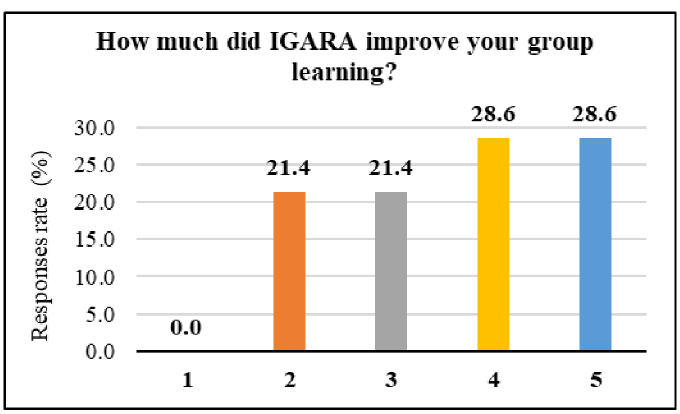

Fig. 5. Improvement in group learning.

As a result of encouraging collaborative studies, there was a small improvement in group learning capacity, when compared to initial question 7 in Table 1. We can see in Figure 4 that there were no answers for the worst case and that for the best case, there was an increase from 21.5% to 28.6%.

In addition to collaborative learning, this research sought to disseminate Educational Robotics. Figure 6 shows how much IGARA stimulated the participants' interest in robotics. We identified that there was a good acceptance on part of students regarding the stimulus for robotics. This indicates that material made available and activities proposed by research fulfilled their devised purpose.

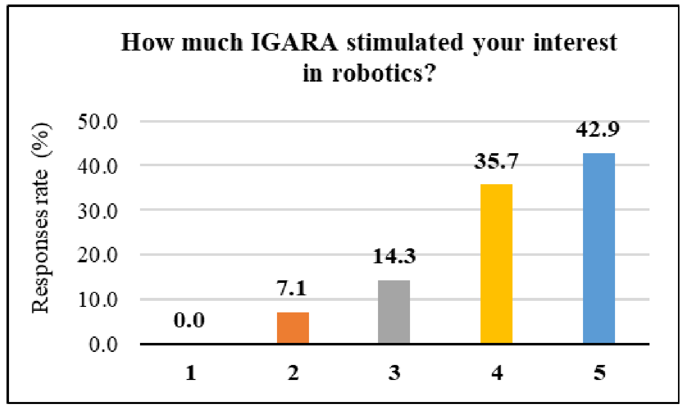

Fig. 6. Stimulating interest in robotics.

In order to capture students' opinions on the research carried out, an open question was made available, in which they could freely comment on the experiences gained from the experiment, also informing of positive points and opportunities for improvement. We highlight 3 students who openly cited the improvement in collaborative learning practiced in groups and knowledge exchange provided by IGARA groupware. As one of the objectives of this research was to promote collaborative learning through groupware, we concluded that objective had been achieved.

We also emphasize that both groupware and teaching materials used were very well evaluated in students' comments. We also emphasize difficulties presented, such as problems when accessing the Internet and the lack of experience with virtual classes.

D. Students Observation during Intervention

All meetings related to this research were carried out by virtual means, abiding to the quarantine due to the current Covid-19 pandemic. Observations were noted during virtual meetings. Interactions by chats and messages between groups were also considered.

We noticed that students were very excited to start participating, especially because of the prospect of working with robotics. However, in the very week when activities were scheduled to start there was a major power outage at the site where the IGARA groupware server was hosted, causing a 7-day delay before activities could start.

Concerning group formation, students displayed a calm attitude and attempted to pick the groups based on their affinities. This is an important point because in that way they would feel safer to work as a team.

During the activities development phase, students were receptive to new knowledge and motivated to proceed. They solved the proposed exercises quickly and accurately, indicating that they were aware of all deadlines.

We noticed that after the first week the number of messages related to doubts subdued, indicating that they were already feeling more confident to solve the challenges, considering that they continued to solve activities quickly.

When the exploratory study was concluded, we realized that many expressed satisfaction for having participated and inquired about the continuation of the research with the Multi-agent Systems. There was a clear interest in participating in other practical activities, even if carried out in a virtual environment.

VIII. Conclusions

Positive feedback from students with regards to IGARA indicates functionality and practicality of the environment to support Electronics and Robotics disciplines, as it stimulated their interest in aforementioned areas and facilitated collaborative learning.

We emphasize another positive aspect of this research related to the use of electronic circuit simulators and robotics projects. Such tools provided an additional incentive in terms of knowledge construction, creativity and autonomy during the execution of previously planned collaborative activities.

The greatest contribution of this research was related to the students' perceptions about collaborative learning. The interaction between students and the IGARA environment provided them with an opportunity to reason on the importance of collective, engaging and cooperative activities, which make up a set of fundamental actions for collaborative work while applied to different learning styles.

During this research, some difficulties were detected, such as poor access to the Internet, mainly on students' end; constant power outages at the site where the computer server was located, which led to a delay in commencing activities as well as a delay for students to complete the Final Questionnaires. We intend to move forward with this research and include an agents' community for the next intervention, when we trust to be able to carry out a complete study, seeking to overcome difficulties and correct points for improvement.

Because it has been well evaluated and well-executed, this approach, as described, has proven to be promising for future activities. Thus, as future work, we also intend to expand the target audience including many more participants from different locations and with much more content to be explored.

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References

[1] Y. Xie, Y. Qiu, Y. Huang, J. Li, Y. Liu and J. Wu, "The Construction and Effect of the MOOC-based One Plus Three Teaching Model During the COVID-19 Pandemic," 2020 Ninth International Conference of Educational Innovation through Technology (EITT), 2020, pp. 199-204, doi: 10.1109/EITT50754.2020.00042.

[2] S. Chiruguru, "The Essencials Skills of 21st Century Classroom (4Cs)", 2020, doi: 10.13140/RG.2.2.36190.59201.

[3] S. Abesadze and D. Nozadze, "Make 21st Century Education: The Importance of Teaching Programming in Schools", 2020, International Journal of Learning and Teaching, pp. 158-163, doi: 10.18178/ijlt.6.3.158-163.

[4] J. Estevez, G. Garate and M. Graña, "Gentle Introduction to Artificial Intelligence for High-School Students Using Scratch," in *IEEE Access*, vol. 7, pp. 179027-179036, 2019, doi: 10.1109/ACCESS.2019.2956136.

[5] D. N. A. Jawawi, N. Ibrahim, S. A. Halim, R. Mamar, N. Mohamed and R. Tumeng, "Adaptation of Project-Oriented Problem-Based Framework for Teaching Computer Programming," 2017 7th World Engineering Education Forum (WEEF), 2017, pp. 844-849, doi: 10.1109/WEEF.2017.8467073.

[6] M. Drini, "Using new methodologies in teaching computer programming," *2018 IEEE Integrated STEM Education Conference (ISEC)*, 2018, pp. 120-124, doi: 10.1109/ISECon.2018.8340461.

[7] S. L. Ong and J. P. W. Ling, "Low-Cost Educational Robotics Car Promotes STEM Learning and 21st Century Skills," *2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, 2020, pp. 467-473, doi: 10.1109/TALE48869.2020.9368487.

[8] K. Yoshino and S. Zhang, "Construction of Teaching Assistant Robot in Programming Class," *2018 7th International Congress on Advanced Applied Informatics (IIAI-AAI)*, 2018, pp. 215-220, doi: 10.1109/IIAI-AAI.2018.00049.

[9] J. S. Kay and J. G. Moss, "Using robots to teach programming to K-12 teachers," *2012 Frontiers in Education Conference Proceedings*, 2012, pp. 1-6, doi: 10.1109/FIE.2012.6462375.

[10] J. McLurkin, J. Rykowski, M. John, Q. Kaseman and A. J. Lynch, "Using Multi-Robot Systems for Engineering Education: Teaching and Outreach With Large Numbers of an Advanced, Low-Cost Robot," in *IEEE Transactions on Education*, vol. 56, no. 1, pp. 24-33, Feb. 2013, doi: 10.1109/TE.2012.2222646.

[11] P. J. Guo, J. White and R. Zanelatto, "Codechella: Multi-user program visualizations for real-time tutoring and collaborative learning," 2015 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC), 2015, pp. 79-87, doi: 10.1109/VLHCC.2015.7357201.

[12] I. Matazi, A. Bennane, R. Messoussi, R. Touahni, I. Oumaira and R. Korchiyne, "Multi-Agent System Based on Fuzzy Logic for E-Learning Collaborative System," 2018 International Symposium on Advanced Electrical and Communication Technologies (ISAECT), 2018, pp. 1-7, doi: 10.1109/ISAECT.2018.8618737.

[13] A. M. M. Lopes, J. F. d. M. Netto, R. A. L. de Souza, A. B. Mourão, T. O. Almeida and D. P. R. de Lima, "Improving Students Skills to Solve Elementary Equations in K-12 Programs Using an Intelligent Tutoring System," *2019 IEEE Frontiers in Education Conference (FIE)*, 2019, pp. 1-9, doi: 10.1109/FIE43999.2019.9028363.

[14] M. Alencar, J. F. Netto and F. Morais, "A Sentiment Analysis Framework for Virtual Learning Environment", 2021, Journal Applied Artificial Intelligence, v.35, pp. 520-536, doi: 10.1080/08839514.2021.1904594.

[15] L. Soh, N. Khandaker and H. Jiang, "I-MINDS: A Multiagent System for Intelligent Computer - Supported Collaborative Learning and Classroom Management", 2008, I. J. Artificial Intelligence in Education, pp. 119-151,

[16] P. Dillenbourg, "What do you mean by 'collaborative learning'?, in Collaborative-learning: Cognitive and Computational Approaches", Oxford: Elsevier, 1999, pp.1-19.

[17] D. Xinyu and L. Min, "Design of Computer Supported Collaborative Learning System Based on Learning Contract," 2008 International Conference on Computer and Electrical Engineering, 2008, pp. 181-184, doi: 10.1109/ICCEE.2008.129.

[18] C. A. Ellis, S. J. Gibbs and G. L. Rein, "Groupware: some issues and experiences", 1991, In *Communications of the ACM, v. 34, n. 1, 1991,* P. 38-58.

[19] K. Ehrlich, "Designing Groupware Applications: A Work-Centered Design Approach", in D. Smith, "Knowledge, Groupware and the Internet", 2000, Boston: Butterworth Heinemann, vol.1, cap. 7, pp. 137-170.

[20] R. Hayes, R. Watson and R. Boston, "Groupware", in S. Gladding, "New Developments in Group Counselingt", 1997, Greensboro, NC: ERIC/CASS, vol.1, pp. 81-83.

[21] P. Balaji and D. Srinivasan, "An Introduction to Multi-Agent Systems". In: D. Srinivasan and L. Jain. (eds) "Innovations in Multi-Agent Systems and Applications - 1. Studies in Computational Intelligence", 2010, vol 310. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-14435-6_1

[22] D. N. A. Jawawi, N. Ibrahim, S. A. Halim, R. Mamar, N. Mohamed and R. Tumeng, "Adaptation of Project-Oriented Problem-Based Framework for Teaching Computer Programming," 2017 7th World Engineering Education Forum (WEEF), 2017, pp. 844-849, doi: 10.1109/WEEF.2017.8467073.

[23] T. O. Almeida, J. F. de M. Netto and M. L. Rios, "Remote robotics laboratory as support to teaching programming," 2017 IEEE Frontiers in Education Conference (FIE), 2017, pp. 1-6, doi: 10.1109/FIE.2017.8190472.

[24] M. Ghazal, F. Haneefa, S. Ali, Y. A. Khalil and A. Sweleh, "A framework for teaching robotic control using a novel visual programming language," 2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS), 2016, pp. 1-4, doi: 10.1109/MWSCAS.2016.7870095.

[25] P. Abreu, M. R. Barbosa and A. M. Lopes, "Robotics virtual lab based on off-line robot programming software," 2013 2nd Experiment@ International Conference (exp.at'13), 2013, pp. 109-113, doi: 10.1109/ExpAt.2013.6703040.

[26] A. Stetsenko, "The transformative mind: expanding Vygotsky's approach to developed and education", 2017, New York, NY: Cambridge University Press.

[27] M. Topçiu and J. Myftiu, "Vygotsky Theory on Social Interaction and its Influence on the Development of Pre-School Children", 2015, European Journal of Social Sciences Education and Research, pp. 172-179, doi: 10.26417/ejser.v4i1.p172-179.

[28] S. Mishra, S. Alok, "Handbook of Research Methodology: A Compendium for Scholars & Researdhers", 2017, Delhi: Educreation.

[29] D. Tofan, M. Galster, P. Avgeriou, D. Weyns, "Software Engineering Researchers' Attitudes on Case Studies and Experiments: an Exploratory Survey", 2011, IET Seminar Digest. 10.1049/ic.2011.0011.