The system robustness SOLL in student learning process

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Abstract. The Internet of Things (IoT) is a network composed of various objects and devices connected to the Internet, which has great potential for education.
In order to verify the potential of IoT in an interdisciplinary approach of the science curriculum in the 3rd Cycle of Basic Education the Smart Objects Linked to Learning (SOLL) project, which is an interactive, dynamic and interdisciplinary learning platform, supported by a set of technologies that collect and store data from a greenhouse for later interdisciplinary analysis has thus developed.
The aim of this article is to show, from a mixed methodology approach, the robustness of the SOLL educational platform in an interdisciplinary learning process. Through student surveys and questionnaires and focus group interviews with teachers, the obtained data show, in general, that this platform responds to the new learning community structure, by adopting a different learning model, based on the exploration of interests and the enrichment of educational experiences.

Keywords: Education, Technology, Internet of Things, Learning, Curriculum

1 Introduction

"Technologies are in society and bring new challenges, needs and possibilities" ([1], p.62), offering "additional tools for the search of information and knowledge" ([2], p. 167). The European Commission [3] note that "digital technologies have an impact on education, training and learning through the development of more flexible learning environments adapted to the needs of a highly mobile society".
According to OCDE, "students learn better science if they see the point of what they learn. Relating the scientific concepts learnt in class to the everyday life of children or, more generally, showing the relevance of what is taught to everyday life problems makes science more attractive – and its teaching and learning more effective." ([4], p. 93); "conducting experiments and investigations gives students an entry point into the work life of scientists, and a better understanding of its empirical dimension." ([4], p.58); "computers and digital devices are well suited to support the acquisition of

procedural knowledge through repetition and drilling" ([4], p. 42) and also develops computer skills" ([4], p. 52). However, "computers and other digital screens are often seen as the rivals, if not the enemies of books. Looking up information and ideas on computers in class helps break these two misconceptions, and helps students learn to find information, as well as other ideas and perspectives about the subject" ([4], p. 79.
The OCDE point out that "good teachers will find the right dosage with other, more active learning practices" ([4], p. 38), because in order to translate it into effective improvement of learning, the teacher must ensure that the use of technology is appropriate and values the learning in question and that it be framed in the current pedagogical practices of the teacher and the preconceptions of the students; the activity should be structured so that the students have to take some responsibility and have the opportunity to develop active participation; it is essential to promote in students reflection on the underlying concepts and relationships, creating moments of discussion, analysis and reflection; the focus should be on the research activity by developing skills in data collection and analysis; it should clarify the relationship between the use of technologies and the process of teaching and learning; the sharing of findings and ideas within the class group should be encouraged [5] .
The IoT introduced "a novel paradigm that is rapidly gaining ground in the modern wireless telecommunications scenario" [6] which allows, through sensors, to connect objects to the Internet so that information about the environment or activity can be obtained which will provide feedback and control [7]. According to Aldowah et. al [7], new forms of information exchange lay the foundation for more interactive and personalized learning" and real-time data are useful for analyzing actions, interactions, preference trends and changes in student skill levels [7]. The teacher remains "essential for guiding students to and through learning objects" and "must also take students away from the variety of disconnected experiences to develop meaning and assimilate their new knowledge, skills and emotions" ([8], p. 35). So, the IoT is applicable to education because, students explore real-world situations in order to "build their own knowledge" ([9], p.116) through the collection of real-time data, issued by these connected environments [10], and allowing for the exploration of subjects that meet the interests and contexts of students and their community.
In order to put these concepts into practice the SOLL platform [11] based on the construction of a greenhouse, monitored by sensors which, through the IoT, transmitted real data constantly updated to the platform in real time was created. From this, the students performed a set of activities, which fulfilled the Essential Learning of the subjects of the 3rd Cycle of Basic Education, and interacted with the environment, acquiring new knowledge. To access this learning platform [12] both teachers and students needed to provide authentication.

2 Methodology

As the study focuses on emancipatory knowledge, which aims to expose the ideologies that condition access to knowledge and actively operate in the transformation of this reality [13], we position ourselves in a socio-critical paradigm, a theoretical perspective which, according to Coutinho ([14], p. 362), is "characterized by greater dynamism in the way of facing reality, greater social interactivity, greater proximity to the real due to the predominance of praxis, participation and critical reflection, and transformative intentionality". Therefore, aiming for the development of practical and innovative solutions to the serious problems of education [15], the development of effective learning environments and the use of natural laboratories to investigate teaching and learning [16] and the fact that research does not take place in the context of the researcher's action, this study used the method of Design-Based Research. According to Wang and Hannafin [17], Design-Based Research is a systematic, flexible methodology designed to improve educational practices through interactive analysis, design, development, and real-world implementation. For Barab and Squire [18] this is not an approach, but several approaches, developed in real contexts, with the intention of producing new theories, artifacts and pedagogical practices with potential to impact learning. It is assumed to be mixed in nature, since the combination of the quantitative method and the qualitative method makes it possible to cover a larger field of research possibilities by raising the public's ideas while quantifying opinions. This happens, according to Teddlie and Tashakorri [19], in a parallel mixed design, in which the use of qualitative and quantitative methods occur simultaneously. Data collection techniques were chosen from the options proposed by Teddlie and Tashakorri [19]: observation techniques, focus groups, and questionnaire survey. In this study, a probabilistic approach was used, since the selection of subjects was intended to be random in order to exclude the systematic error that affects non-probabilistic samples [20]. Within this sampling, a random cluster sampling was chosen, which allowed for the equivalence of clusters at the same level. Thus, based on the words of Charles (1998), who states that the sample is directly related to the type of problem to be investigated, the sample had the following characteristics: 154 students, 79 (51%) boys and 75 (49%) girls in 6 classes of 8th grade; 14 teachers (prof.) distributed by the subjects of mathematics (Mat), natural sciences (NS), physics and chemistry (PC), geography (Geo) and information and communication technologies (ICT).

A questionnaire was designed for students to answer at the following times: before the activities, pretest; at the end of each proposed activity and after the completion of the activities, post-test, with answers on a Likert scale. This questionnaire was validated by conducting it on a sample of teachers and students from another context. For the teachers, the focus group method was chosen, as the format of "guided discussion", is intended to verify the "interactions" that are created [22], to observe the degree and nature of the agreements and disagreements between participants [23]. In order to meet the objective and collect data on the impact of IoT on student learning processes, these instruments, questionnaires and focus group guides, were constructed based on the work of the following researchers: Welchen and Oliveira [24]; Parellada and Rufini [25]; Souza [26][26]; Neves [27];Guimarães [28]; Neves and Boruchovitch [29]; Knuppe [30]; Siqueira and Wechsle [31]; Alcará and Leite et al [28]; Bzuneck [32].

For data analysis, MaxQDA software was used for qualitative data analysis of the teachers' focus group interviews and SPSS software was used for quantitative data analysis of the student questionnaires.

3 Results

Regarding the students' data that compare the impact on learning processes, between the diagnostic survey before the activity (pre-test) and the final survey after the activity (post-test), we chose the Sign Test. This test was selected because it does not have requirements for the form of data distribution, it is only necessary that the data be selected independently and that they can be sorted from smallest to largest, as it does not use the numerical value of the answers nor their difference but only their sign. The fact that relationships can be given meaning is one of the biggest advantages of this test. For $\alpha = 0.05$, the hypotheses for the nonparametric statistical test, sign test, are: H_0: There are no differences regarding the topic between pre-test and post-test, ($X_i = Y_i$; p=0,50) e H_1: There was an improvement in the topic at the end of the activity, ($Y_i > X_i$, p>0,50, unilateral test). For each learning process statement, which is found in the pre-test and post-test questionnaire survey, Table 1 was constructed.

Table 1. Student results regarding the impact on learning process between the diagnostic survey before the activity (pre-test) and the final survey after the activity (post-test)

	Pre-test		Post-test		Sign test
	Mean	SD*	Mean	SD*	Asymp. Sig. (2-tailed)
Activities with technological support and real data turns more abstract contents into more concrete contents	3,12	0,67	3,35	0,62	0,03
Technologically supported activities using real data allow us to evaluate whether I know the contents	3,22	0,67	3,38	0,63	0,04
Technologically supported activities using real data make it possible to organize complex phenomena so that they can be identified, understood and perceived	3,26	0,66	3,42	0,58	0,06
Teachers give feedback on activities	3,32	0,57	3,24	0,71	0,72
Teachers realize students' difficulties	3,23	0,68	3,27	0,71	0,82
Promote the use of technology for research	3,236	0,71	3,39	0,71	0,05

Regarding student data on the impact on learning process across the four activities, we chose the Friedman Test. For $\alpha = 0.05$, the hypotheses for Friedman Test are: H0: There is no difference throughout the activities e H1: There are differences throughout the activities. For each learning process statement, which is found in each one of the four activities performed, table 2 was prepared.

Table 2. Student outcomes regarding impact on learning process across the four activities

Hypotheses:	Acti 1	Acti 2	Acti 3	Acti 4	Friedman test
	Mean Standard deviation				Asymp. Sig.
This technology-supported, real-data activity makes the most abstract contents into concrete	3,16 0,54	3,13 0,70	3,22 0,66	3,24 0,64	0,40
In this technology-supported, real-data activity activity, I got activity feedback faster	3,15 0,75	3,21 0,65	3,27 0,64	3,30 0,60	0,56
In this technology-supported activity using real data, the teacher realized my difficulties	2,84 0,95	2,84 0,88	2,87 0,89	2,89 0,90	0,96
Technologically supported activities using real data allow us to evaluate whether I know the contents	3,24 0,58	3,25 0,62	3,03 0,60	3,36 0,61	0,32
Technologically supported activities using real data make it possible to organize complex phenomena so that they can be identified, understood and perceived	3,22 0,58	3,19 0,63	3,40 0,58	3,27 0,62	0,06

Regarding the impact of technology in general and the IoT in particular, on student learning processes, teachers' statements are presented in table 3.

Table 3. Teacher results on the impact of technology on student learning process

Are there any pedagogical benefits for students learning using technological resources? If so, which ones?	PC1 - whenever they touch anything, I think they learn more consistently, the content is consolidated, they know what they are doing... they have no critical spirit ...
	PC2 – I think so, look ... I mean, it's not as linear as that, I already realized that there are a lot of students that we do in the classroom ... the experimental part is shown on video and nothing was left ... but, I always think that what they see or what they mess with ... that is better perceived ... I think it's always better ... now at the PowerPoint level ... teaching with PorwerPoint, the feedback I have is that kids like it ... they like to see it ... they like it all written on the board ... they they really like to see ... they like the image, videos, mainly...
	PC3 – this makes it easier in terms of being a perception of an image ... if you have to draw the picture on the board, already ... perfect in PowerPoint ends up helping to understand better ... and it has an advantage .. and I think they like ... the video to break the routine of a particular class style, isn't it ... the simulations ... and the live experiences ... and there are a lot of simulations that help us repeat when we cannot do the experiment again ... to repeat in large classroom ...
	NS2 – they feel closer to what they like, which is their interests ... at least at first, it's not ... later sometimes ... when it comes to the content part ... but it's more appealing to them, is a different way of exploring certain subjects ... in a much more interesting way ...
	Geo2 – Often students have to be guided. It is not ... also sometimes do not know very well how to distinguish the essential from the accessory ... have to

	be very oriented ... and even in research ...
	Geo1 - I think the fact that we use a lot of technology they don't develop certain skills and certain skills that they should develop ... for example, let's talk about computers and the internet ... they don't know how to search ... it's ... they don't know .. . they are so used to having this flood of information that they don´t know how to see what they can use, which is to use ...
Do you consider that the use of IoT promotes interdisciplinarity?	NS1 and Geo1 – yes it does promote ... and we could even use this in the future to develop more aspects
	PC1 – yes ... we can easily join 4/5 areas
	Geo1 e PC1 – moreover we have seen this project ...
	PC2 and 3 – yes... that too... no doubt about that ...
	Geo2 – It depends...
	NS2 – it can ... it can allow ...
Do you consider that IoT facilitates knowledge building?	Mat1 – it depends on the contents ... the contents covered and the orientation we give them ...
	NS1 – yes ... and deep down it forces them to interpret, to be critical of the data they are receiving ... so it ends up building, consolidating and structuring knowledge.
	Geo1 – yes, as it motivates them more to ... if we are always give lectures, half will not be understood and so…
	PC2 – there is no better construction of knowledge that is not like that ... I think it's the best way ... even if they realize that ultimately all areas of knowledge are bound together ... and that complement ... in terms of knowledge...
	PC3 – I think so ... that's great ... that are interconnected...
	NS2 and Geo2 – yes, of course... yes...
	Mat1 – and in this age where we are
Do you consider that any improvements come from the design of activities that IoT allows to do?	Geo1 – yes, if complemented with other strategies... I think just ... only this type of strategy will not work, I believe that if this type of learning is vulgarized that students will become more sloppy, more... because they have the easiest things and the motivation will eventually diminish over time because it is not new anymore and so ... I think that as a complement to other strategies and other forms of teaching, notably the more traditional ones that shouldn't disappear in my opinion...
	NS1 – it's the question of diversifying
	PC3 – more continuously, it is not ... where students, for example, in a week only devote themselves to the project and do the very thing connected ... work when they feel it is to evaluate ...
	PC2 – yes, there was a lot of interruption ... maybe even took a lot ... from the students' point of view ... a lot of seriousness about the job ...
	NS2 and Geo2 – yes... of course ... that's what they control ..
	Mat1 – more motivating... acquire more knowledge than if it were theoretically...
During this period did you use IoT to develop classroom activities? If so, what activities	Geo2 – yes ... several times ... I consulted the IPMA website when I gave the weather and climate, the kids consulted the IPMA website at home to bring the weather forecasts for the next class ... the PORDATA that the kids also consulted and collected data, Kahoots, Socrative ... Mentimeters, to start a theme that they had to choose...
	NS2 – research ... also for research ... I also used Socrative, I used a lot of data from the internet where they had to do research and bring it back ... in

	class ...
	Mat1 – Not much ... because the content I've been giving didn't give much to it…
	Geo1 - I always use the internet ... always ... almost every class ... I use Google Earth a lot, Google Maps ... and also PORDATA ... which are also real data ...
	PC2 – nothing ... we moved to the light ... we made a Question Class because we had already finished the sound ... we were to take advantage of the ultrasonic sensor but then we ended up and did the evaluation and we didn't talk anymore
	PC3 – there was no chance ... we didn't use it ... I'm being honest ...
Why did you resort to this type of activity or not?	NS2 – because there was a need ... because I'm used to doing that and there are in certain content and at certain times a need to resort to that ... the subjects did not make sense to be worked on if there was no appeal for a certain type of ... internet of things ...
	Mat1 – with the circumference can still do with Geogebra ... Not quite the internet of things is more software ... in math some content I cannot adapt and then usually do not use kahoot and so ... I don't usually use ...
	Geo1 – I resorted to it because the materials demand it ... and are relatively easy to use tools that are available...
	PC1 – I think the contents are not very appropriate to get real data...
	PC3 – here it was for lack of time ... here it was really lack of time and class dynamics ... because otherwise I would have gone back and would have applied ... lack of time in the sense of not having adequate dynamics to make exceptions. .. that were no exceptions but that ... you can't ... we can't extend the time anymore but otherwise maybe we could try ... I don't know if next year comes to purpose...
	PC2 – lack of time ... yes, but lack of time is a bit of their dynamics ... because I never missed ... I never missed all year ... I missed a day to go on a study visit…
What do students think about these activities?	Geo1 and 2 and NS2 – they like it ... – yes, they like it ... they always like ...
	PC1 – when we do such a thing they always like it because it's the data they collect...
	PC2 – never spoke of that…
	PC3 – when they were asking ... I had feedback at the moment ... I know what they showed me I saw some questions ...
How do you evaluate the activities developed?	PC2 - if you want me to tell you ...when they were doing the activity they were getting involved and doing the activity very quickly ... it was even good for flexibility ...
	PC3 – when they were asking ... I had feedback at the moment ... I know what they showed me I saw some questions ...

4 Discussion

From the results of the questionnaires applied to the students obtained before, during and after the activities, it appears that they agree with all the statements. However, they agree little with the statement “in this activity with technological support and use of real data the teacher was aware of my difficulties during the activities”. Evidently, they were unaware of the students' difficulties because even though the students

agreed with the statement "teachers give feedback on activities", the degree of agreement decreased from the pre-test to the post-test. In a statistically significant way, we can verify that, in the opinion of the students, the activities with technological support and real data turns more abstract contents into more concrete contents, the activities with technological support and real data allow for evaluation if they know the contents, promoting the use of technology for research.
From the results obtained in the focus group interview to the teachers, it is verified that they consider that: the use of technological resources adds value to learning, as students find it motivating, and better consolidates learning if they act on something, if they see an image or a video. This is because, in the teachers' opinion, it breaks the routine or style of class, but they need to be very well organised. However, some teachers consider that technology does not allow for the development of skills that students should develop because they do not know how to use a search engine. Technology can be a good tool for this development, but you have to practice using it; the use of the IoT promotes interdisciplinary study, as was clearly proven by this project; the IoT facilitates knowledge building because it compels students to interpret, be critical of the data they are receiving, and ultimately builds, consolidates and structures knowledge, and students enjoy it because they are working with their data and any improvement comes from the design of activities using the IoT, but complemented by other strategies.
Although teachers see advantages in using technology in general, and the IoT in particular, and recognize that students enjoy these activities, few teachers use this tool in the classroom. Those who use technology rely solely on software, or open data feeds, and use these tools because they are easy-to-use and are available, there are contents that require it, and because it is customary to do so to teach certain content.
Teachers who do not use technology say they do not know how to adapt it to the content, or else the content is not adapted to use the technology. Lack of time and classroom dynamics are other reasons why technology is not used in the classroom. Teachers admit that students were involved when carrying out the activities, which responds to the intended flexibility and interdisciplinary aspect. However, they state that they did not talk to the students about the activities, that is, they did not give feedback on the performed activities.

5 Conclusion

By analyzing the results of teachers and students, it can be seen that this platform, which through previous exposure is echoed in the current directives recommended by the OECD [4], responds to the current problems of teaching-learning since it brings numerous benefits to the development of children, especially in the construction of their identity. This is especially relevant as it can lead the child to become autonomous and facilitate the acquisition of new knowledge, thus enabling their effective development of knowing how to use personal resources to face the adversities that they will need to overcome throughout their lives [24]. However, the "bureaucratic and professional logic structure of the school system and the schools profoundly influence the organization of work and create a vicious circle that is difficult to break by reinforcing stability" [33] because the IoT in the classroom cannot be seen solely as a means of content acquisition. It is, above all, a change of mentality and attitude towards the teaching and learning process. "The teacher must accompany, motivate, dialogue, and be a leader and a mediator, by fostering and mediating positive human interaction" ([34], p. 28 e 29).

In short, it is generally agreed between teachers and students that the SOLL platform demonstrates robustness for the interdisciplinary development of the learning process of 3rd cycle science students. Therefore, teachers should take advantage of the IoT to "plan and structure the educational process in an open and flexible way, allowing for diversified approaches, where motivating, dynamic and current teaching resources are implemented, using an interactive and cooperative methodology, using an interactive and cooperative methodology, and various communication channels" ([34], pp. 28) as the OECD states ([4], p. 38) "good teachers will find the right dosage with other, more active learning practices".

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