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An Educational Method Based on Student-Generated Questions

Julia Gil Llinás*
University of Extremadura, SPAIN

Luis Manuel Tobaja Márquez
Colegio Salesiano "María Auxiliadora", SPAIN

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Abstract: This paper describes an experience based on the use of an active method in which students of a basic physics course prepare multiple choice questions (MCQs) to prepare for exams in the subject. The objective of the research was to provide the students with a method that would enhance their desire to learn physics, and consequently lead to an improvement in their meaningful learning. The participants were 57 first-year students from various engineering degrees. The quasi-experimental design with pre- and post-tests and a control group is described. The results showed that students who use the method of generating MCQs to prepare exams sometimes improve their learning significantly in comparison with the control group. The method also provides a new way to detect students' misconceptions about the concepts covered in class, which thus allows the evolution of their knowledge to be evaluated. Finally, it should be noted that the students valued the method used positively.

Keywords: *Misconceptions, participatory learning, student-generated questions, teaching and learning physics.*

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Introduction

This study was originally inspired by the conclusions reached in a previous experience in which one of the authors participated (Abad et al., 2017). Within the framework of an educational project, a group of second-year students prepared questions on various topics in photonics. Multiple choice questions (MCQs) generated by the students and reviewed by the teacher were used to develop an educative game as well as to elaborate the final test for the subject of Basic Photonics (4th semester of a Telematics engineering degree).

Tanel and Erol (2008) indicate that students are often not motivated to learn physics, with lecture-based teaching being a hindrance to their achieving meaningful learning of the topics. As Kemmis (2001) notes, new and better educational theories are needed to put forward and develop ideas, in this case theories and models, about teaching and learning that contribute to improving higher education. Recently, a broad consensus has emerged to promote, from different educational fields, the empowerment of learners as protagonists in their own learning. Active approaches are part of this line of work, which involves greater commitment and involvement of learners through participation in the construction of new learning (Oliver-Hoyo et al., 2012).

This paper describes an experience based on the use of an active method that consists of students developing MCQs in a basic physics course of the 2nd semester of various engineering degrees. In view of the outcome of earlier research (Berry & Chew, 2008), the quality of the questions was not considered, but their quantity was.

In this context, the question arises: Does the method based on MCQs improve the students' academic performance, and therefore lead to more significant learning of the contents of a basic physics course?

When reviewing the MCQs, we found misconceptions about the contents of the topics discussed. This led to our considering the students' previous knowledge about the various topics that were discussed, as well as correcting conceptual errors that remained even after the instruction. These issues are fundamental if meaningful learning is to be achieved (Ausubel et al., 1983).

Literature Review

With the implementation of the European Higher Education Area in Spain, teaching strategies went from being centred on the teacher to being centred on the students. Consequently, the methodological work had to be based on methods stemming from the principle of active learning (Ministry of Education, Culture and Sports, 2003) in which students

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* **Corresponding author:**
Julia Gil Llinás, University of Extremadura, Badajoz, Spain. ✉ juliagil@unex.es

acquire responsibility for their own learning by participating in the construction of new learning. It implies a commitment on the part of the student to the tasks, as well as a reflection on what they do and the results they obtain. The student becomes a constructor of knowledge and not a mere receiver of information (Gil et al., 2010; Muñoz-García et al., 2013). Activities that involve asking questions and soliciting reasoned responses from learners have been documented to be beneficial in learners' construction of knowledge (Yu, 2009), promoting active learning and fostering positive attitudes towards learning new content (Hsu & Wang, 2018; Yu & Wu, 2020).

Formative assessment techniques are fundamental components of classroom interactions in which teachers can obtain information about student learning whenever possible. Other skills are also observed, such as communicating and illustrating scientific ideas or imagining situations related to the acquired knowledge. Traditionally, however, teachers ask questions and assess the students' responses, but do not investigate the students' contributions to classroom interactions (Almuntasheri, 2016). For instance, a teacher can explore learners' prior knowledge using questioning strategies and thus make their ideas explicit for the whole class, as well as other learning tasks that provide evidence of their understanding (Black, 2003; Ruiz-Primo & Furtak, 2006). However, sometimes students do not feel ready to give responses in the presence of their peers, so that other strategies must be tried. An example of such a strategy may be that they themselves prepare the questions they are going to answer, taking into account that it is no less important for them to be capable of writing well-formulated questions based on their acquired knowledge and be able to rank them in order of importance (Rothstein & Santana, 2011). From the point of view of cognition, according to Vygotsky's theory of education, students who are given this type of task face the need to develop higher-order skills, e.g., the so-called ''zone of proximal development'' (Chaiklin, 2003; Vygotsky & Cole, 1978). Students who have mastered the subject content and have reflected deeply on it, are able to ask good questions and provide acceptable answers. For novice learners, the instructor's assistance is important to guide the first attempts. Once this preliminary phase has been completed, question writing has shown to be a successful tool to design activities involving higher-order intellectual abilities.

Draper (2009) emphasizes the educational benefits of involving the students in co-creating educational content such as student-generated questions. Indeed, writing questions for assessment purposes is often beyond the students' capacity since, although they are familiar with the content, their knowledge of the facts is insufficient, and additional cognitive and metacognitive skills must be developed. One such skill is the active use of precise scientific language to clearly express facts or scientific concepts in the form of questions and statements (Banks, 2008; Duschl & Osborne, 2002; Lemke, 1990). In this context, providing the students with opportunities to improve their scientific language under the instructor's supervision is a very helpful strategy to scaffold their intellectual autonomy. For instance, when students were taught to formulate questions about textual material, a significant improvement in their reading comprehension was observed (Koch & Eckstein, 1991). More recent studies have shown how the generation of questions in an educational setting like that of the University of Rwanda with third-year teacher-education students indirectly improved their questioning skills, skills that are not developed naturally but through practice (Bahati et al., 2017).

As Foos (1989) mentions, books on how to study effectively in university recommend writing down possible exam questions, and this method seems since then to have become the subject of systematic studies (Chin & Brown, 2002; Chin & Osborne, 2008). In this context, different factors like the kind of questions posed by students (Watts & Alsop, 1995; Watts, Alsop et al., 1997; Watts, Gould & Alsop, 1997), the identification of learning problems (Maskill, & de Jesus, 1997), or the difficulties that learners have when posing questions about abstract concepts (Olsher & Dreyfus, 1999) have been studied. Student-generated questions have also been used to design formative and summative assessment tasks (Bell & Cowie, 2001; Dori & Herscovitz, 1999). In particular, student written MCQs have been the subject of recent studies. For example, Hutchinson and Wells (2013) found that letting the students generate their own MCQs did not have any negative impact on their learning process. Also, Sanchez-Elez et al. (2014) found that Computer Science and Engineering students who had written MCQs performed better in their final exams. Horgen (2007) found clear learning benefits that the author attributed to improved student motivation because of allowing the students to write their own tests within the framework of two Information Technology courses.

According to Bates' study (Bates et al., 2014) about the quality of MCQs drafted by physics students, this can be even better than their teachers expect. Other recent research reports better results by combining student-generated questions with teacher-generated questions rather than using only student-generated questions (Yu & Chen, 2014).

Contrary to what might be thought, Berry and Chew (2008) found that the significant predictor was the number of questions generated rather than the level of the questions. Also, low-achieving pupils showed more attention to the question generation task, and the more questions they generated about the course content, the more their performance increased compared with those students who had produced fewer questions.

Two different types of knowledge about the same phenomenon can coexist in one student: the academic (more formal and rigorous) and the personal empirical-practical (informal, implicit, but quite predictive), which do not always coincide (Mazur, 2009). Knowing the students' misconceptions is a necessary starting point and designing instruction to correct the flawed aspects of these misconceptions is the teacher's job. This change is what is called conceptual change. Understanding learning as a process of conceptual change means confronting, explicitly and deliberately, both types of knowledge through educational techniques and resources.

The most important condition for this conflict to generate an authentic conceptual change is that the student becomes at the same time fully aware of their "a priori" ideas and reflects upon the phenomena in which each is involved. Questionnaires constitute one of the most widely used research techniques to discover alternative ideas in class (Gil et al., 2010). In this context, a widely used fast way for such detection is that of closed-ended questions, such as multiple-choice questions, in which students are given a statement or a graphic or symbolic representation and are asked to choose between several pre-determined answers, in which one of the distractors coincides with the preconception or error that is sought. In this paper, the novelty lies in the fact that these questionnaires are prepared by the students themselves, and it is, therefore their own statements of questions and responses that reveal misconceptions about the subject in question, without the influence of any external agent.

As mentioned above, good results had been obtained from an experience in which student generated MCQs were used to draft the final examination within the context of an educative game (Abad et al., 2017). With this present work, we wanted to check whether the results are repeated outside the game context and that the MCQs the students generated do not form part of the subject's final examination and thus avoid the possible learning or memory effect. In this scenario, there arises the question: “Can the method based on MCQs generated by the students more actively render the preparation of evaluation tests as well as improve their learning skills in a basic physics course?”

With respect to research based on student-generated MCQs, we do not know of any bibliographical references apart from the present work which deal with the topic of misconception detection, a vitally important topic in teaching and learning science.

Methodology

In this study, an experience based on the generation of MCQs by first-year engineering students in a basic physics subject is presented in which the topics covered were: General Theory of Fields, Gravitational Interaction, Electrostatic Interaction, and Magnetic Interaction. A quasi-experimental design with a control group and an experimental group was carried out. The results used to compare the two groups were acquired from pre- and post-tests.

The Research Sample

The research involved 57 students from Industrial Design and Product Development and Geomatics Engineering (Topography) at the Centro Universitario de Mérida (Spain). The students, in their first year, were distributed in five groups of 15-16 components during the normal development of their physics course in a teaching framework that includes lectures, laboratory sessions, and tutorials. The experimental conditions could not be established in any extreme degree, so that a noteworthy aspect of the study is that it was conducted under natural teaching conditions.

Research Design

The design was developed during the in-person tutorial sessions assigned to the subject in the study plan for the first year of engineering at the University of Extremadura, Spain. These sessions are taught in small groups of 15-16 students and are used as revision tasks or to resolve any doubts about the content of a topic that had been covered in lectures during the previous week. Each student participated in four sessions, one session in a week (non-consecutive) in the second semester of the official course. Each of the tutorial sessions was dedicated to one of the four topics named above.

The method used was indicated in the following. Before the corresponding tutorial workshop, the students were asked to develop a set of MCQs that summarized the topic that had already been discussed in class. Once the MCQs had been prepared, and the correct answers indicated, the students sent the document electronically to the primary researcher through the virtual campus of the University of Extremadura, which uses the Moodle platform. This instructor reviewed the document before the said session.

The first two sets of questions elaborated on the topics of General Theory of Fields and Gravitational Interaction and served as training for the students to become familiar with the generation of MCQs. To do this, they were asked to prepare a set of four closed multiple-choice questions for each topic. In the two corresponding presential tutorial sessions, the MCQs were shared in a whole-class session, with the students being able to discuss both their format and their content, and any errors were corrected where necessary. In these discussions, the teacher could intervene.

The third and fourth tutorial sessions were used to evaluate the process. For the third session, the students were randomly divided into a control group and an experimental group. Both groups were told that in the third tutorial session, they would be asked to resolve an evaluation test that consisted in answering a set of MCQ-type questions generated by the teacher. For this third session, the students of the experimental group were asked to prepare for the test by drafting a 10-question questionnaire as a summary of the topic of Electrostatic Interaction, which they would send electronically to the teacher before the aforementioned session. The control group was not given any method to prepare for the exam. For the experimental group, only the students who sent the set of MCQs to the teacher prior to the evaluation test were taken into account.

For the fourth session of the presential tutorials, the topic discussed was Magnetic Interaction. The method to evaluate the process was the same, with the only difference that the students from the control group of the 3rd session became the experimental group and vice versa.

Analyzing of Data

A quasi-experimental experience with a control group and an experimental group was carried out. The data to compare the two groups was obtained from the results of pre- and post-tests prepared by the teacher.

In the data analysis, the same sequence was always followed: once the data of the pre-test and post-test variables had been collected, their descriptive statistics were calculated. Then the normality of the distributions was studied in order to decide which inferential test was the most convenient to apply. For reasons of space, only the most relevant results will be presented. The statistical analysis of the data was performed with the IBM SPSS Statistics 20 software program.

As pre-test results, the marks obtained for the final exam of the subject Physics1, taken from the participants in this experience during the semester prior to this work, were considered. This examination consists of a traditional test that comprises a theoretical part of closed multiple-choice questions and a practical part of several problems that the student has to solve. The instructor responsible for the Physics1 course did not participate in this experience.

Table 1. Normality Tests for the Pre-Test Data of the Experimental and Control Groups

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Mark pre-test	EG	0.127	27	.200*	0.975	27	.723
	CG	0.120	30	.200*	0.955	30	.233

[a] Lilliefors significance correction.
* This is a lower limit for the true significance.

The normality of the pre-test variable was checked for the control (CG) and experimental (EG) groups. The results are presented in Table 1. To evaluate the post-test dependent variable, two tests of 10 MCQs were used, one per topic, prepared by the teacher in order to avoid the possible "learning effect". These tests comprised 10 items, each of which was a closed multiple choice question, and each correct answer scored one point, i.e., the maximum score that could be attained was 10. The items were similar or the same as those which had been used in the traditional evaluation tests of previous years. Both the Kolmogorov-Smirnov and the Shapiro-Wilk normality tests yielded results that did not allow one to consider that the distributions of the post-test results followed a normal law.

Findings

As pre-test results, the marks obtained for the final exam of the subject Physics1, taken from the participants in this experience during the semester prior to this work, were considered. In order to test the working hypothesis, it was necessary to check the homogeneity between the control and experimental groups for the pre-test data. Table 2 lists the descriptive statistics for the pre-test variable for the control (CG) and the experimental (EG) groups.

Table 2. Descriptive Statistics of the Pre-Test Variable of the Control and the Experimental Groups

Group			Statistic	Std. Error
EG	Mean		3.9315	0.33481
	95% confidence interval of the mean	Lower limit	3.2433	
		Upper limit	4.6197	
	Median		3.9200	
	Std. dev.		1.73972	
CG	Mean		4.0893	0.30468
	95% confidence interval of the mean	Lower limit	3.4662	
		Upper limit	4.7125	
	Median		4.1250	
	Std. dev.		1.66878	

The mean of the CG is greater than the mean of the EG, but, looking at the confidence intervals for the mean at 95%, one observes that the interval of the CG (3.4662-4.7125) completely contains that of the EG (3.2433-4.6197). Everything suggests that there are no significant differences between the means of the two distributions, and that we start from two homogeneous distributions. For greater security, once the normality of the pre-test distributions for both variables (Table 1) had been checked, we performed a student's t-test for independent samples. The results of this test confirmed that for a level of significance $\alpha=.05$ there was no significant difference between the means of the two groups ($p_{value}=.728$), which allowed both data distributions to be considered as homogeneous.

To evaluate the post-test dependent variable, two tests of 10 MCQs were used, one per topic, prepared by the teacher in order to avoid the possible "learning effect". The results for each topic are presented below.

Results of the Evaluation of the Topic Electrostatic Interaction

A total of 57 students participated (27 EG, 30 CG). As indicated above, the experimental group prepared the post-test by drafting a test that consisted of a set of 10 MCQs about the topic of Electrostatic Interaction, and the control group prepared the post-test in a traditional way. The statistical analysis of the results appears in Table 3.

Table 3. Descriptive Statistics of the Electrostatic Interaction Post-Test Variable

Group			Statistic	Std. Error
EG	Mean		4.04	0.327
	95% confidence interval of the mean	Lower limit	3.37	
		Upper limit	4.71	
	Median		4.00	
	Std. dev.		1.698	
CG	Mean		4.27	0.321
	95% confidence interval of the mean	Lower limit	3.61	
		Upper limit	4.92	
	Median		4.00	
	Std. dev.		1.760	

The mean increased in both cases, while the median increased (from 3.92 to 4.00) for the experimental group but decreased in the control case (4.12 to 4.00). In this case, both the Kolmogorov-Smirnov and Shapiro-Wilk normality tests yielded results that did not allow one to consider that the distributions of the post-test results followed a normal law. Hence, the Mann-Whitney U-test was adopted to compare the two distributions, taking a 5% significance level (Table 4). From the results ($p_{value}=.490$), it can be deduced that there are no significant differences between CG and EG.

Table 4. Summary of the Mann-Whitney U Hypothesis Test for Independent Samples of the Electrostatic Interaction Post-Test Results

	Null hypothesis	Test	Sig.	Decision
1	The Group categories have the same distribution for the Electrostatic Field	Mann-Whitney U test for independent samples	.49	Keep the null hypothesis

Shown are asymptotic significances. The significance level is .05.

To assess the degree of learning acquired by the participants, the normalized mean gain (G) of each group was calculated by the expression below (Márquez et al., 2017):

$$G = \frac{score\ postest - score\ pretest}{10 - score\ pretest}$$

The result of the gain is not only greater for the experimental group (M = .0041, SD = .34992) for both the mean and the median but is negative for the mean in the case of the control group (M = -.0255, SD = .3849) (Table 5). Student's t hypothesis test for equality of means for independent samples did not confirm (t (54) = .300, p-value = .765) that there were significant differences between the two distributions (EG and CG) regarding the normalized gain variable.

Results of the Evaluation of the Topic Magnetic Interaction

In this case, a total of 55 students participated (24 EG, 31 CG). To check the effect of the independent variable (preparing an exam through the students' own generation of MCQs), the 24 EG students were part of the CG that evaluated the topic Electrostatic Interaction, and the 31 CG students were those forming the EG of the previous topic

Table 5. Descriptive Statistics of the Normalized Gain Between the Pre- and Post-Test Electrostatic Interaction Data for the Control Group and the Experimental Group

Group			Statistic	Std. Error
EG	Mean		**.0041**	.06863
	95% confidence interval of the mean	Lower limit	-.1372	
		Upper limit	.1455	
	Median		.0399	
	Std. dev.		.34992	
	Minimum		-0.83	
	Maximum		0.56	
CG	Mean		**-.0255**	.07028
	95% confidence interval of the mean	Lower limit	-.1693	
		Upper limit	.1182	
	Median		.0131	
	Std. dev.		.38492	
	Minimum		-1.00	
	Maximum		0.64	

The descriptive statistics for the Magnetic Interaction post-test variable appear in Table 6. In this case, the mean and median were greater in the case of the experimental group. The 95% confidence intervals, (3.32, 4.55) for the control group and (4.10, 5.65) for the experimental group, only barely overlap, which seems to indicate that the distributions of the two variables would be different.

Table 6. Descriptive Statistics of the Magnetic Interaction Post-Test Variable

Group			Statistic	Std. Error
CG	Mean		3.94	0.300
	95% confidence interval of the mean	Lower limit	3.32	
		Upper limit	4.55	
	Median		4.00	
	Std. dev.		1.672	
EG	Mean		4.88	0.373
	95% confidence interval of the mean	Lower limit	4.10	
		Upper limit	5.65	
	Median		5.00	
	Std. dev.		1.825	

The same conclusion can be drawn from observation of the box-and-whisker plot of the distributions (Figure 1) where the median of the control group is below the lower limit of the distribution of the experimental group.

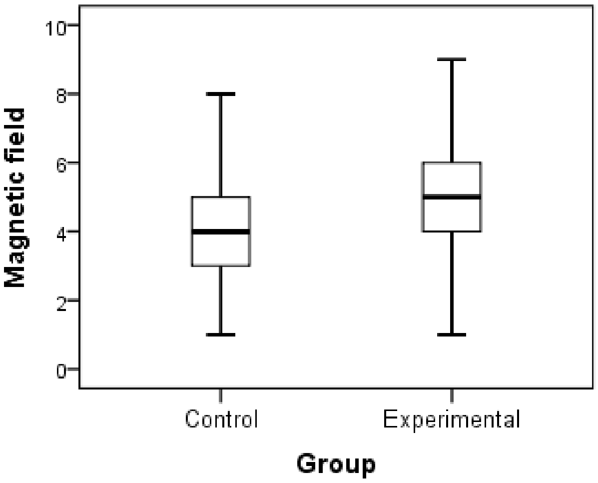

Figure. 1. Box-and-Whisker Plot of the EG and CG Magnetic Interaction Post-Test Data.

According to the K-S and S-W normality tests, the distribution of the Magnetic Interaction post-test variable did not follow a normality for CG, so a non-parametric hypothesis test was applied. The Mann-Whitney U test for independent samples confirmed that the distributions of the two variables were significantly different at the 5% level of significance (Table 7). Both the EG mean (4.88) and median (5.00) were greater than those of CG (3.94 and 4.00, respectively).

Table 7. Summary of the Mann-Whitney U Hypothesis Test for Independent Samples of the Electrostatic Interaction Post-Test Results

	Null hypothesis	Test	Sig.	Decision
1	The Group categories have the same distribution for the Magnetic Field	Mann-Whitney U test for independent samples	.037	Reject the null hypothesis

Shown are asymptotic significances. The significance level is 0.05.

Detection of Misconceptions From the Set of Questions Elaborated by the Students

Although it was not one of the main objectives of this study, when correcting the set of questions elaborated by the students, we encountered some conceptual errors and misconceptions. These were above all related to physical concepts that require a considerable level of abstract knowledge, such as the concept of field. This is coherent with many research studies that have identified how hard it is to modify students' prior conceptual schemes in a stable way.

Meaningful learning of key scientific concepts, such as a field, is a necessary condition for the scientific training of students, for their understanding of physical phenomena and their knowledge of the principles that undergird various technological applications (Llancaqueo Henríquez et al., 2003). Below are three cases of the misconceptions that appeared most frequently. The boldface responses are those that the student considered to be the true solution.

1.- Thinking that the disturbance at a point in space only exists when the witness charge is there. Of the 35 students who participated in this task, 11 presented an item referring to this characteristic, and 10 of them noted this error. An example:

An electric field exists in:

a) Any region of space where there is an electric charge in motion.

b) Any region of space where an electric charge at rest experiences a force.

c) Any region of space where a charge exists.

d) All are true.

2.- Giving a "real" meaning to the field lines and confusing them with the intensity value of the field at a point. An example is shown in the following item in which the student author, asked about the meaning of answer a), replied that the field rotates around the wire.

A wire through which an electric current flows:

a) Produces a circular magnetic field around the wire.

b) Produces a magnetic field proportional to the current intensity.

c) Will generate a field inversely proportional to the distance from the wire.

d) All are right

3.- Considering that the electrical interaction is an interaction between charges, and the field is the place in space where the charges interact, not actually the vehicle of that interaction, a preconception which was documented by Furió-Mas and Aranzabal (2001). An example is the following item:

Electrical charges, both positive and negative, exert an attractive or repulsive influence on the space around them. What is this space called?

a) Coulomb space.

b) Electric potential.

c) Charge density.

d) Electric field.

To finish the presentation of the results, we shall present the data obtained through an opinion questionnaire about the students' own generation of questions as a teaching and learning method. The responses of all the students who participated in this study were taken into account, since at some point in the teaching-learning sequence they had had contact with the method described here. Table 8 gives the results of the students' degree of involvement when preparing the sets of questions, their attitude towards this method, and their overall assessment of the method used. In addition, more than 52.6% of the students indicated that this method entails greater dedication, and 58% consider that this method has allowed them to better understand the subject.

Table 8. The Students' Assessment of the Teaching and Learning Process.

Aspect studied		Nº of students (%)
Degree of involvement		
	0%	0
	25%	1 (1.8 %)
	50%	3 (5.3 %)
	75%	38 (66.7 %)
	100%	15 (26.3 %)
Attitude		
	Very negative	0
	Negative	0
	Indifferent	5 (8.8 %)
	Positive	46 (80.7 %)
	Very positive	6 (10.5 %)
Overall valuation		
	Useless	0
	Of little use	4 (7.0 %)
	Quite useful	20 (35.1 %)
	Definitely useful	25 (43.9 %)
	Very useful	8 (14.0 %)

Discussion

As has been seen, the statistical analysis of the post-test results revealed an improvement in the EG students' performance. The means of the post-test values reached when evaluating the Electrostatic Interaction topic were 4.04 for EG and 4.27 for CG (which already had a higher pre-test mean). Nevertheless, it cannot be considered that the two groups have significantly different results, findings which coincide with those of Yu and Wu (2020). We hypothesize that drafting questions for the first time may exceed a student's cognitive load, minimizing the potential benefits of the task (Wu et al., 2018). But these results show a positive evolution in favour of the EG if the maximum possible value of 10 is taken into account and these results are expressed in terms of the normalized mean gain, being equal to +0.0041 (positive) for EG but -0.0255 (negative) for CG.

In the case of the Magnetic Interaction topic, the EG mean was 4.88 compared with 3.99 for CG. The difference was significant according to the Mann-Whitney U hypothesis test for independent samples. It is clear that the time the students spend in designing the MCQs was of use in improving their results. We hypothesize that this is due to their better understanding the theoretical principles, which helped them overcome the associated conceptual difficulties (Abad et al., 2017).

Taking into account the results of the opinion questionnaire, the students show a positive (80.7%) or very positive (10.5%) attitude towards the teaching-learning process, with more than 93% showing a high degree of involvement with the method. They consider that the usefulness of the method is quite satisfactory (35.1% useful, 43.9% quite useful, and 14.0% very useful). In a student's words: "It seems to be a good study method; it is also pleasanter than the traditional method."

This study's results are in line with those reported by Teplitski et al. (2018) and Hancock et al. (2018). In addition to their students expressing a high degree of satisfaction and having better scores on the tests carried out, the aforementioned authors emphasize the importance of correcting and evaluating the questions the students created at some point in the MCQ preparation process. In the present study, this feedback process took place during in-person tutoring sessions prior to the final test.

Conclusions

The results show that students who use the method of generating MCQs to prepare exams improve their learning, as verified in the two cases that were evaluated. This finding is in line with that of Teplitski et al. (2018) who stress how important it is to correct the questions in the process in a way similar to what was done in the present study. In this sense, when the students were in the EG either they at least improved their degree of learning as was verified through the normalized mean gain variable, or significant differences were directly verified in the mean value of the post-test variable, as in the case of the second topic evaluated. It must be borne in mind that in these types of experiences there are variables that cannot be controlled, as was revealed by the satisfaction survey, which showed that some students were not 100% involved in the task and did not have much confidence in the results of the experiment at the beginning.

Perhaps the fact of obtaining better results, in terms of gain, made the EG in the first case participate more actively in the case of Magnetic Interaction, hence the significant difference in favour of the EG on this occasion.

Finally, it should be noted that the student-generated MCQ method constitutes a good way to explicitly discover their misconceptions about what has been covered in class. It also allows the evolution of their knowledge to be evaluated and achieves the cognitive conflict generating in them a contradictory situation between what they already know (prior knowledge) and the new knowledge. In addition, the data that have been presented seem to indicate that the students express satisfaction with this form of working on the content. Although, as mentioned above, the quality of the questions generated by the students was not taken into account, there is no doubt that the students at least developed such skills as the active use of rigorous and grammatically correct scientific language to transmit established ideas in the form of questions and statements.

Recommendations

It must be borne in mind that the method proposed here is a hypothesis that needs to be verified or rejected by teaching practice extended to complete courses and other fields of physics, which opens new problems for research. The study was designed using multiple choice answers. It could be tested with open questions and/or problems designed by the student. Further studies for a larger number of students, with different teachers, would allow better generalization of the research outcomes. The method could be set out collaboratively, with the students themselves reviewing the questions and answers they had prepared before sharing them with the whole group. This proposal would be in line with that of Hancock et al. (2018) who found a significant improvement in their students' results.

Given that the goal was for the students to acquire meaningful learning, one might ask whether the improvement in learning attained by the students who proposed the MCQ's is maintained over time. To this end, it would be appropriate to carry out studies to verify the persistence of the knowledge obtained.

As the proposed method is shown to be effective in detecting students' misconceptions, this work strategy can also be used to detect students' prior knowledge about the topics to be discussed. It is known that these alternative ideas have a stubborn persistence in a student's conceptual scheme, so that it should be checked whether the students in whom some misconception has been detected maintain it and show it in their response to the evaluation test.

Limitations

As with most innovative educational interventions that take advantage of constructive student-centred learning, the additional instructional time required for the intervention must be taken into account when introducing our method into classes, which will also require the instructor(s)' intensive dedication. Despite the adoption and integration of technology in educational settings, it will be necessary to mobilize more human resources to carry out such studies. Furthermore, the task of drafting questions may involve an intrinsic cognitive load that exceeds the students' cognitive load, thus minimizing the potential benefits the task might provide. The present report has largely relied on quantitative data compilation methods, and is therefore restricted. Data collected using more qualitative methods could provide a broader perspective than that of the present research.

Authorship Contribution Statement

Gil: Concept and design, data acquisition, statistical analysis, data analysis / interpretation, drafting manuscript. Tobaja: Critical revision of manuscript, editing/reviewing, supervision.

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