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Analysis of the Use of Clickers in an Electrochemistry and Corrosion Course

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ABSTRACT
Providing undergraduates with the best and most effective teaching methods has always been a concern. Therefore, over the years several devices and new learning technologies have been introduced into the classroom. Thus, to seek innovations in teaching, clickers, or personal response systems, were used in a chemical engineering undergraduate course, specifically in the electrochemistry and corrosion class, at the University of Campinas, Brazil. In the end of the course, the students answered a questionnaire about the satisfaction and effectiveness of their use in the classroom. The responses were analysed and a greater acceptance and effectiveness were reported by students.

Keywords: clickers, electrochemistry classes, chemical engineering, personal response systems.

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I. INTRODUCTION

Chemical Engineering is an area of knowledge considered new, since its appearance dates from the end of the 19th century. Faced with the intense growth of industries, especially those related to the oil industry, it is one of the most important and attractive profession. The course of Chemical Engineering of University of Campinas (UNICAMP) was created by decree nº 52.255 of July 30, 1969, but its implantation happened only a few years later, in 1975, when the chemical and petrochemical pole in Paulínia city (São Paulo, Brazil) was established. The implementation of the Paulínia refinery (Replan) gave rise to the largest petrochemical pole in Latin America. As a result, many other companies established in the region and, the demand for qualified labour increased. The lack of skilled workers led to their import from other states and, this situation began to change when, the Unicamp Chemical Engineering undergraduate course was founded. The course of electrochemistry and corrosion was introduced in the 1980s and, aiming at the excellence, new teaching methodologies have been introduced over the almost 40 years of its existence.

Teaching methodologies are constantly debated, studied, and modified, always with the aim of improving and making the learning process more dynamic (Brookshire, 2006). Teaching/learning using direct interaction with students through electronic devices began in the 1960s, and they were initially applied in the exact science areas (Judson et al., 2002). Rapid technological evolution has driven the development of devices that help this interaction between students and teachers during teaching. Among these are clickers, known by a variety of 'labels', such as personal response systems (PRSs), student response systems (SRSs) and or audience response systems (ARSs) (McDonough et al., 2015).

Clickers were first used in US universities in the 1980s in different areas of higher education, such as chemistry, mathematics, political science, biology, history, law, and philosophy (Zhu, 2007). They consist of small transmitter devices that allow each student to respond in a matter of seconds to multiple-choice questions formulated by the teacher. These are presented as slides, allowing students to receive instant feedback of their answers during class time (Varo, 2014).

Different forms of instruction that integrate clickers are commonly found in the literature (Chien et al., 2016). The simplest way to use them is to ask students to answer a question individually. When the instructor asks the question, which is usually displayed on a screen, students can click on the buttons on their remote devices to answer it. A receiver connected to a computer collects student responses. The computer software records and summarises them. The results are automatically presented to the class in a visual format, usually through a histogram. This feedback is visible to the whole class, providing the teacher with information on the level of understanding of the students and guidance on how to adapt the content of the class, allowing the teacher to assess the knowledge and level of preparation of the students (Blasco-Arcas et al., 2013; Sun, 2014).

Some studies report that students participate more when devices are used in the classroom, and they view positively the use of clicker-based technologies because of their anonymity (Caldwell, 2007). The use of these resources in classrooms, in addition to making the class more dynamic, allows the teacher to verify whether the students have actually done the reading of the content made available for the lesson, so that they have a more active attitude towards the learning process (Richardson et al., 2015). Since the introduction of clickers, ARS-based technologies have evolved in terms of their forms, capabilities, and availability. The technology has been adapted for use in mobile handsets (e.g., GO and Socrative clicker) and directly online through the internet (e.g., GoSoapBox, QuestionPress, etc.) (Hunsu et al., 2016).

The purpose of the present study was to describe the use of clickers in electrochemistry and corrosion classes and, analyse the improvement of teaching (or lack of it) by the application of an investigative questionnaire.

II. EXPERIMENTAL PROCEDURE

The clickers were used in Electrochemistry and Corrosion classes (Acronym: EQ-622) in a classroom of 54 students. The classes are taught by addressing scientific-technological knowledge of electrochemistry, chemical kinetics and thermodynamics, always associating them with practical cases of corrosion. The contents of the discipline were: electrochemical reactions; electrolyte solutions; transport of ions; electrochemical cells; energy storage; forms and classification of corrosion; electrochemical corrosion; and corrosion in the chemical and petrochemical industry.

The clicker apparatus used was the Clicker Handheld Student Response Device KG3EI (CPS Pulse™; eInstruction® Corporation) with Response software (version 6.73.148.70252; eInstruction® Corporation) as shown in **Figure 1**.

A B

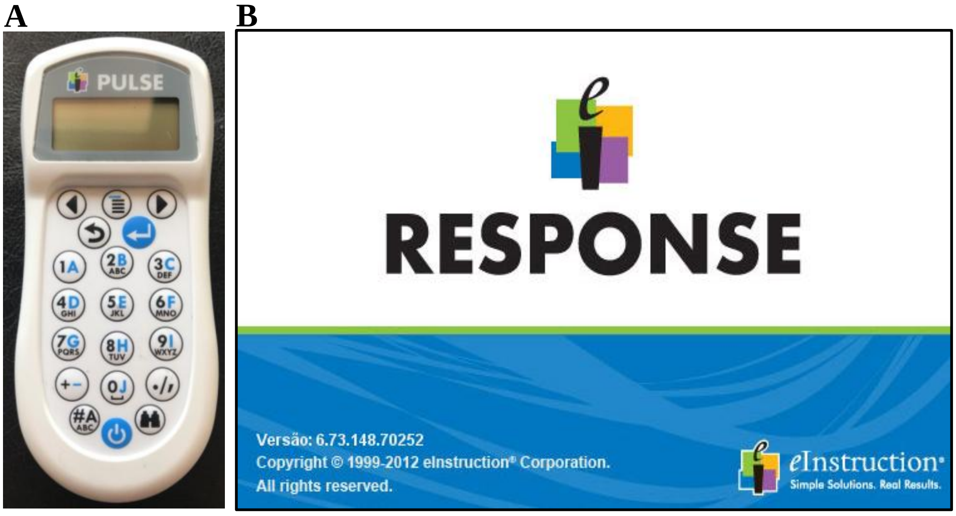

Figure 1. A: Clicker Handheld Student Response Device KG3EI; and **B**: Response software used for data collection.

The teaching methodology consisted of conceptual questions embedded in multimedia presentations covering the course content. At the beginning of theoretical classes, the clickers were distributed to the students, who signed a receiving list. At the end of the class, the clickers were returned formally. During the classes, questions were formulated and applied with the help of the clickers. The questions were of the following types: multiple-choice, true-or-false, a series of answers, or a short answer. When needed, the teacher could instantly insert new questions regarding the topic being taught.

The questions were prepared before the classes on the subjects of the discipline's content. Usually, they contained texts, or photographs of corroded pieces in industrial chemical processes, or corrosion occurring in the students' daily life. When questions involved photographs of corroded pieces, for example, the discussions involved the types and forms of corrosion, what factors had given rise to the corroded piece or item of equipment, how students could correlate the corrosion with the description of an incorrect specification of the material selected for that process fluid, and what steps they would take as future engineers to prevent that corrosion.

In this way, the clickers allowed the students and teacher to receive instant feedback during class time. Thus, the teacher was able to assess the accuracy of the students' responses and, if any doubts were detected, he could re-explain the topic until he was sure that the class had fully understood the subject.

At the end of the course, a questionnaire was completed with questions about the practicality, dynamism, efficiency, resolution of doubts, learning process and self-evaluation of the use of these devices during the classes. The objective of the questionnaire (**Table 1**, responded to anonymously) was to determine and quantify the success of using the clickers in the classroom, as well as the difficulty in handling them. In addition, the students could write any positive and negative points and give suggestions. The answers were analysed and, based on the data obtained, a report was created on the positivity of the use of clickers in electrochemistry and corrosion classes.

Table 1. Questionnaire applied in the end of the course.

Focus	**Questioning**
Practicality	Was the software used in class practical, providing simple and easy handling?
Dynamism	The use of clickers has given more dynamism to the classes.
Efficiency	The clickers were helpful in consolidating your knowledge, leading to more effective learning.
Resolution of doubts	The use of clickers in the classroom prompted questions, allowing any doubts to be better resolved.
Learning	The use of clickers facilitated your learning.
Self-analysis	The use of clickers allows you to self-evaluate your knowledge in front of your classmates.

III. RESULTS AND DISCUSSION

The first aspect of clickers when used in the discipline of Electrochemistry and Corrosion was to analyse the practicality and the initial difficulties of their use in a chemical engineering classroom. At the beginning of the course, principally in the first two classes, the students underwent intensive training in the use of clickers. In these classes where the use of clickers was introduced, the time spent between the students' arrival and the beginning of the class was greater, reaching up to 15 minutes; this included the time given for instructions on the use of the devices. One of the main factors responsible for this delay was the initial difficulty of installing the software and its connection to the multimedia system. It took about 10 minutes to get the system up and running. This delay was due to lack of practice in the use of the equipment. From the third class onwards, the clicker system worked satisfactorily. In general, the time between distributing the clickers and the beginning of the class was 5–7 minutes.

About this aspect, when asked 72% of students considered that the devices were easy to handle and operate, as shown in **Figure 2.** The purpose of this question was to find out whether the students felt that the clickers were easy to handle (very practical or practical) or whether they had any difficulties regarding the manipulation of these devices (impractical or strongly impractical). Only 8% of students said the technology was confusing and 20% remained neutral. It can be concluded that for the majority of respondents, clicker handling was not an obstacle to the application of this teaching methodology.

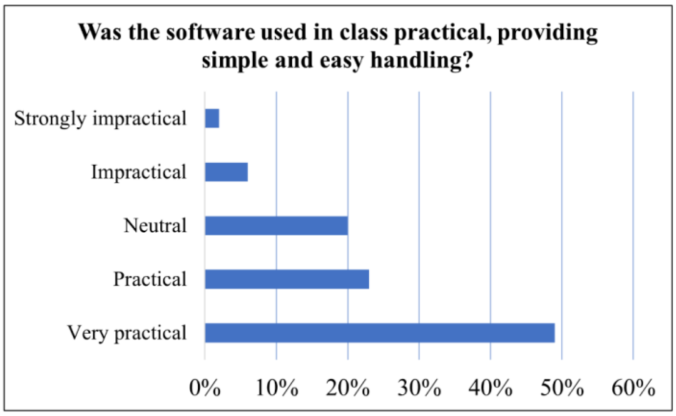

Figure 2. Practicality of the use of clickers in the Electrochemical and Corrosion course as reported by the students.

The second interesting aspect to relate was that the students presented relaxed and motivated behaviour, leading them to participate more in the discussions of the different corrosion processes and their implications in industry. It seems that memorisation of the knowledge acquired was more effective compared to a conventional class without the use of clickers. This could be confirmed in the subsequent classes: when a previously discussed subject was re-addressed, the index of correctness of these questions was high.

On the evidence of student motivation, when questioned about 70% of the responses indicated that clickers had a positive influence on the dynamism of the classes, possibly caused by the greater dynamism of the classes caused by the clickers, while 15% were neutral (**Figure 3A**). The remaining responses showed that 15% of the students did not feel any difference in the dynamism of the classes when it came to the use of clickers. It was concluded that the use of clickers in the classroom increased the dynamism of the classes, causing the students to participate more and, possibly, to learn more. This data corroborates several other studies in the literature that affirmed that clickers not only increase the dynamism of classes, but promote a greater participation and discussion in the classroom (Morin et al., 2009; Stines- Chaumeil et al., 2019; Velasco et al., 2013).

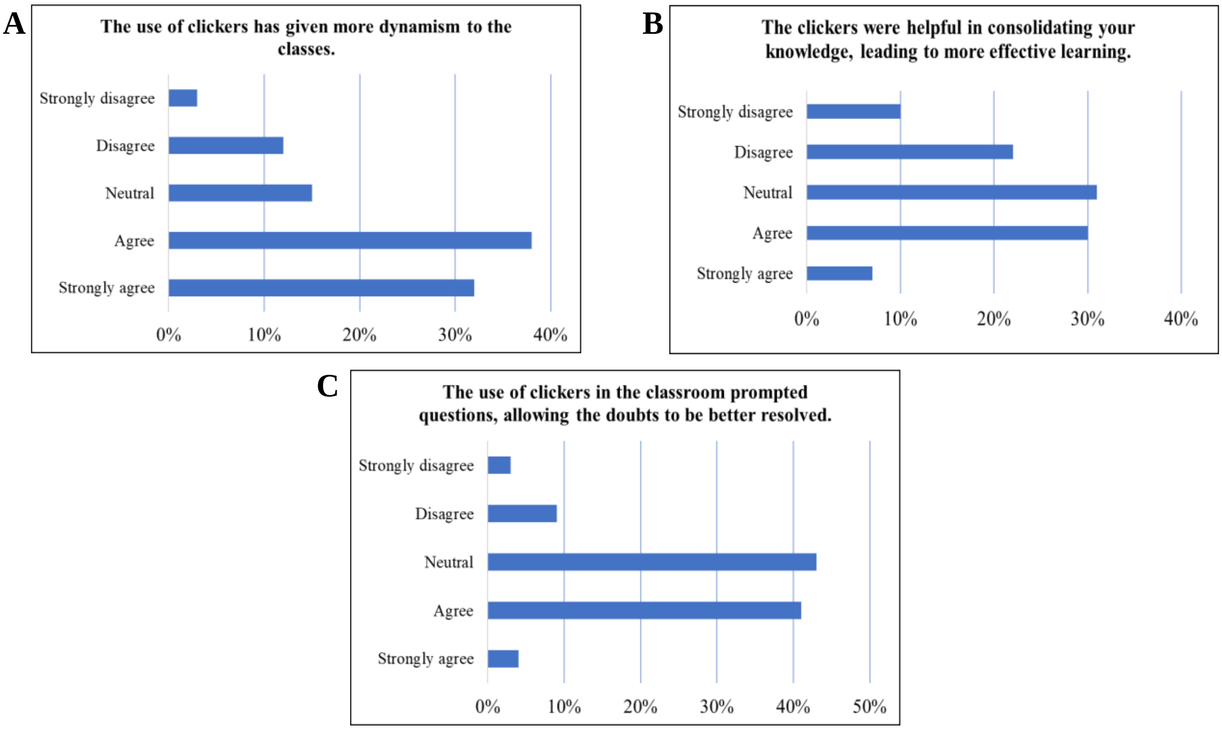

Figure 3. Data obtained in relation to **A**: dynamism; **B**: effectiveness in teaching; and **C**: resolution of doubts through the use of clickers during the course.

Concerning learning efficiency, **Figure 3B** shows the students' opinions on whether clickers influenced the transmission and assimilation of knowledge, since this teaching methodology differs from the traditional. The clickers were helpful in consolidating the knowledge of 38% of students (Agree and Strongly Agree), leading to more effective learning. On the other hand,32% of students (Disagree and Strongly Disagree) answered that they did not contribute to learning. The remaining 31% of the answers were neutral.

A possible conclusion on the outcome of the responses may be based on the different ways in which the students study. As some clicker questions applied in the classroom were intended to review the discipline given, the use of this methodology favoured those students who systematically followed the subject taught and studied the lessons taught after the classes. The students who, by habit, only studied on the eve of the tests chose to abstain or did not notice a difference with the use of these devices. In addition, we have the behaviour of the students in the classroom. Some students wanted only to pass the course (in order to complete their degree); that is, they did not undertake to acquire that knowledge for use in professional life, although many of the questions asked had that as their goal.

Figure 3C shows the influence of clickers on clarifying doubts and the arising of questions during class. So, 45% of respondents considered that the use of clickers improved the clarification of doubts during the class and led to effectiveness in resolving them. The minority (12%) indicated that the use of clickers did not clarify doubts more effectively than did traditional classes. The remaining 43% were neutral. However, the teacher was able to note that the use of clickers encouraged students to discuss further the topic debated in the classroom, thus raising their critical sense and promoting the resolution of doubts.

The last questions concerned the learning process in general; that is, whether learning and self-evaluation were facilitated by the use of clickers. These results are shown in **Figure 4**.

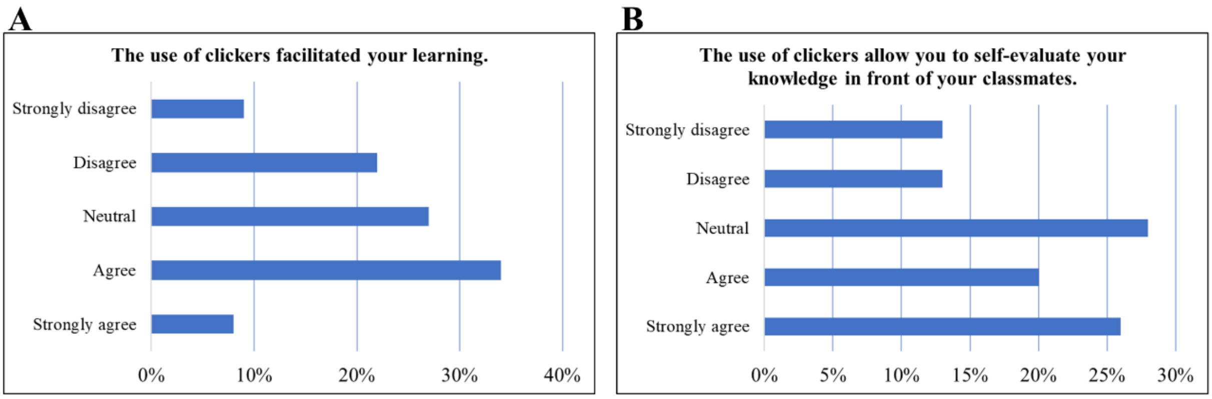

Figure 4. A: the use of clickers in facilitating learning; and **B**: the effect of clickers in allowing self-evaluation by students.

The students who favoured the use of clickers as a teaching tool totalled 46% (**Figure 4A**), while 28% maintained a position of neutrality. The responses that considered that the clickers did not facilities the process of learning amounted to 26%.The data in **Figure 4A** can be correlated with that in **Figure 3B**.

Students who did not study the lessons weekly, or who just wanted to complete the discipline, may be included in the group who declared that there was no improvement in the efficiency of the transmission of knowledge and learning, or were neutral. Another hypothesis for the high neutrality rate in the answers given may be the lack of comparation that is, the student cannot compare Electrochemistry and Corrosion classes with and without the use of clickers to determine the difference between the two methods. In this sense, the literature lacks comparative research with classes that used and did not use this method of learning (Hunsu et al., 2016).

The research also addressed whether clickers allowed the students to self-assess their knowledge in front of their classmates. Because everyone's response is computed, the student quickly gets feedback as to whether he/she understands the matter along with colleagues. So, the clicker system shows the entire class the percentage of students that had hit/miss the questions. This automatically led to a review of the responses given and, as a consequence, to self-assessment. Regarding self-evaluation, **Figure 4B** shows that 26% of the students said they could not self-assess using clickers. In turn, 44% of the students stated that the use of clickers was useful in evaluating self-knowledge in the classroom.

However, 30% of respondents said that using the clicker system did not increase their self-evaluation, but did not repress it. The majority agreed that their self-assessment was improved. Kulatunga & Rameezdeen (2014) had already reported this positive student perception when applied to their Built Environment course. However, in their article, more than 80% of the students held this view.

In summary, the main goals of the use of clickers in this course, were the practicality and dynamism that these devices offer. We can see these data clearly in **Figure 5**. There seems to be a consensus in the literature concerning these two points as reported by students that, in general, electronic classroom response systems are highly accepted, promote dynamism and encourage greater participation among students (Bartsch et al., 2011). These characteristics were reproduced in this chemical engineering course. However, it is not easy to correlate the effects prompted by the use of this resource with better performance by the students in terms of acquired knowledge (Summerville et al., 2017). In our results, this is expressed by the difficulty of students in recognising other factors directly correlated with an increase in performance or learning. However, our results show that at least 40% of the students recognised that their learning processes benefited. These data are motivators for the continuance and improvement in the use of this technique in this course.

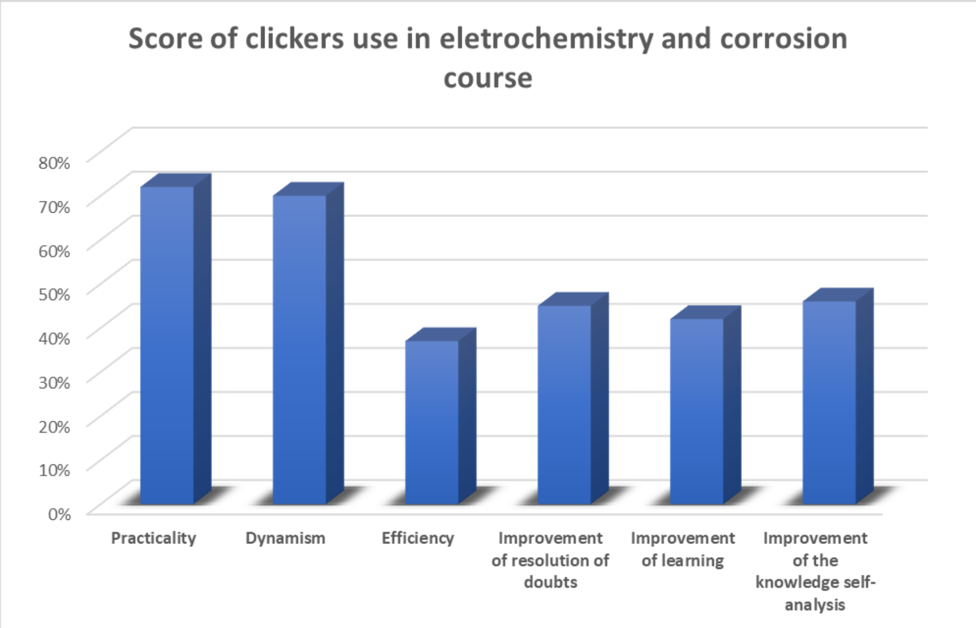

Figure 5. Clicker use scores in the electrochemistry and corrosion course.

In an open question, students were asked about the positives and negatives of using clickers during the course. Selected answers are given in **Table 2**. It is interesting to note the students' perceptions of the positive points that reinforce those already known about the use of clickers: tools for reviewing material, detecting learning failures, giving immediate feedback and increasing participation and motivation during classes. In short, as positive points in agreement with the literature, clickers were found to be innovative and creative educational tools that provide greater efficiency in learning, since they require prior study of the class content and increase the participation and motivation of the students in the classes, making it possible to identify questions they may have and the difficulties they are experiencing with a certain subject (Rana et al., 2016). On the negative side, students reported the problem of students who are not serious about their studies because they cannot be identified. These may hamper the smooth running of classes as well as result in errors in teacher and student assessment of content learning. Despite greater motivation, students also reported problems with discussions unrelated to the course content. However, this was not viewed by the teacher as an important issue, since it was easily controlled.

Table 2. Main positive and negative aspects of using clickers in the Electrochemistry and Corrosion course as reported by the students.

Positive points	Negative points
✓ Appropriate methodology for reviewing the material ✓ Detection of points with learning difficulties ✓ Immediate feedback of knowledge ✓ Increased motivation in class ✓ Increase of interactivity between teacher and students	✓ Students who do not know the answer make random choices ✓ Tumult in class during the distribution and collection of devices ✓ Students who are not serious and cannot be identified ✓ Allow parallel conversations not related to the subject taught hindering the dynamism of the class

Finally, the students could make suggestions. One of them was to insert the 'I do not know' option in response options. For true/false questions, it appears that such an insertion would depend on changes made in the software. For multiple-choice questions, it is indicated in the literature that the ideal number of these alternatives is three or four(Bruno et al., 1995; Rogers et al., 1999). In this case, the question may be asked with three alternatives, adding the alternative 'I do not know'. This would respond to the students' suggestions and, in principle, reduce the possibility of random choices, which could lead to erroneous conclusions regarding the achievement of knowledge by the class.

IV. CONCLUSIONS

In conclusion, the Electrochemistry and Corrosion course seemed to be easily adapted to the use of clickers and their use was helpful in improving the teaching/learning process. With the use of clickers, questions can be related to concrete chemical engineering problems and can be formulated with the use of photographs, graphs, tables, flowcharts, and technical drawings of equipment projects. A teacher who emphasises the issues and leads the students to make their own decisions results in an integration, not only of the scientific-technological knowledge acquired in the courses, but its application in real life. Besides, from this research, the students accepted the clickers very well. These devices can be considered easily handled tools that bring an increase in the learning and participation of students in the classroom. As a suggestion, other chemistry engineering disciplines could use this teaching tool, with some modifications.

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DECLARATION OF INTEREST
The authors declare they have no conflict of interest.

REFERENCES

[1]. Bartsch, R. A., & Murphy, W. (2011). Examining the Effects of an Electronic Classroom Response System on Student Engagement and Performance. *Journal of Educational Computing Research*, *44*(1), 25–33. doi: 10.2190/EC.44.1.b

[2]. Blasco-Arcas, L., Buil, I., Hernández-Ortega, B., & Sese, F. J. (2013). Using clickers in class. The role of interactivity, active collaborative learning and engagement in learning performance. *Computers & Education*, *62*, 102–110. doi: 10.1016/J.COMPEDU.2012.10.019

[3]. Brookshire, R. G. (2006). Teaching Uml Database Modeling To Visually Impaired Students. *Issues in Information Systems*, *7*(1), 98–101. Retrieved from http://www.

[4]. Bruno, J. E., & Dirkzwager, A. (1995). Determining the Optimal Number of Alternatives to a Multiple-Choice Test Item: An Information Theoretic Perspective. *Educational and Psychological Measurement*, *55*(6), 959–966. doi: 10.1177/0013164495055006004

[5]. Caldwell, J. E. (2007). Clickers in the large classroom: current research and best-practice tips. *CBE Life Sciences Education*, *6*(1), 9–20. doi: 10.1187/cbe.06-12-0205

[6]. Chien, Y.-T., Chang, Y.-H., & Chang, C.-Y. (2016). Do we click in the right way? A meta-analytic review of clicker-integrated instruction. *Educational Research Review*, *17*, 1–18. doi: 10.1016/J.EDUREV.2015.10.003

[7]. Hunsu, N. J., Adesope, O., & Bayly, D. J. (2016). A meta-analysis of the effects of audience response systems (clicker-based

technologies) on cognition and affect. *Computers & Education*, *94*, 102–119. doi: 10.1016/j.compedu.2015.11.013

[8]. Judson, E., & Sawada, D. (2002). Learning from Past and Present: Electronic Response Systems in College Lecture Halls. *Journal of Computers in Mathematics and Science Teaching*, *21*(2), 167–181. Retrieved from https://www.learntechlib.org/p/15113/

[9]. Kulatunga, U., & Rameezdeen, R. (2014). Use of Clickers to Improve Student Engagement in Learning: Observations from the Built Environment Discipline. *International Journal of Construction Education and Research*, *10*(1), 3–18. doi: 10.1080/15578771.2013.826754

[10]. McDonough, K., & Foote, J. A. (2015). The impact of individual and shared clicker use on students' collaborative learning. *Computers & Education*, *86*, 236–249. doi: 10.1016/J.COMPEDU.2015.08.009

[11]. Morin, D., Thomas, J. D. E., Barrington, J., Dyer, L., & Boutchkova, M. (2009). The "Clicker" Project: A Scholarly Approach to Technology Integration. In Real Learning Opportunities at Business School and Beyond (pp. 97–107). Dordrecht: Springer Netherlands. doi: 10.1007/978-90-481-2973-7_7

[12]. Rana, N. P., Dwivedi, Y. K., & Al-Khowaiter, W. A. A. (2016). A review of literature on the use of clickers in the business and management discipline. *The International Journal of Management Education*, *14*(2), 74–91. doi: 10.1016/J.IJME.2016.02.002

[13]. Richardson, A. M., Dunn, P. K., McDonald, C., & Oprescu, F. (2015). CRiSP: An Instrument for Assessing Student Perceptions of Classroom Response Systems. *Journal of Science Education and Technology*, *24*(4), 432–447. doi: 10.1007/s10956-014-9528-2

[14]. Rogers, W. T., & Harley, D. (1999). An Empirical Comparison of Three-and Four-Choice Items and Tests: Susceptibility to Testwiseness and Internal Consistency Reliability. *Educational and Psychological Measurement*, *59*(2), 234–247. doi: 10.1177/00131649921969820

[15]. Stines-Chaumeil, C., Paumard, P., & Hooks, M. A. (2019). Incorporating clickers into an enzymology course improves student performance. *FEBS Open Bio*, *9*(4), 562–570. doi: 10.1002/2211-5463.12599

[16]. Summerville, A., Walker, R. J., Wessels, P. M., Spangler, B. R., Walker, B. L., & Lloyd, E. P. (2017). Comparing active learning techniques: The effect of clickers and discussion groups on student perceptions and performance. *Australasian Journal of Educational Technology*, *34*(3), 74–87. doi: 10.14742/ajet.3337

[17]. Sun, J. C.-Y. (2014). Influence of polling technologies on student engagement: An analysis of student motivation, academic performance, and brainwave data. *Computers & Education*, *72*, 80–89. doi: 10.1016/J.COMPEDU.2013.10.010

[18]. Varo, M. (2014). El uso de los sistemas de respuesta interactiva como recurso educativo para la enseñanza de la física en los estudios de ingeniería. *Memorias de Proyectos de Innovación Educativa de La Universidad de Córdoba*, *2013–14*.

[19]. Velasco, M., & Çavdar, G. (2013). Teaching Large Classes with Clickers: Results from a Teaching Experiment in Comparative Politics. *PS: Political Science & Politics*, *46*(04), 823–829. doi: 10.1017/S1049096513001121

[20]. Zhu, E. (2007). Teaching with clickers. *CRLT Occasional Papers*, *22*(22), 1–8. Retrieved from https://tccl.arcc.albany.edu/knilt/images/f/fe/Zhu_Teaching_with_Clickers.pdf

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