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EDUCATION & TRAINING

Fostering Student's Engagement and Active Learning in Neuroscience Education

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Abstract
Neurophobia is a term coined to describe university students' fear of neuroscience, which negatively affect learning. The implementation of new technologies in higher education, such as new response systems, provide an opportunity to improve neurosciences learning and teaching by engaging students. However, most response systems rely on student devices such as clickers. The aim of this study is to illustrate the application of a new digital application for collection of real-time formative assessment data in higher education. Results of this study support the utility paper-based response cards to foster engagement and active learning in higher education, even with complex neuroscience topics, providing real-time formative assessment data without the need for student devices.

Keywords Active learning · Technology-based education · Higher education · Classroom response system

Introduction

Technological applications have transformed our lives and are increasingly taking place in higher education enhancing the learning and teaching process between professor and students [1–3]. Furthermore, it has been reported that most professors agree that expanding educational opportunities can be addressed through the use of technology [4–7]. Unfortunately, most of them fail to implement those advances in their daily classes.

Today more than ever is necessary reinvent the traditional classroom lecture. In fact, there is increasing pressure in higher education to promote students' engagement and participation during the lectures instead of just delivering content. This is specially so, for students who are digital native or millennials and for professors highly motivated to get students more engaged in a meaningful interaction [8].

The new developments in digital technologies provide an opportunity to tackle this challenge. For example, the use of classroom response systems, which consist in any form or technology that provides an opportunity to collect students' answer then visual or graphically displayed to provide feedback, is based on the assumption that effective teaching is directly related with the students' total opportunities of active engagement in class [9–13]. Therefore, the use of technology in class may expand the opportunities of engagement and active learning moving from traditional interaction focused on raising-hands to more interactive technology-based classroom response system such as the use of clickers [14–17]. In fact, providing every student with opportunities to respond may be considered an effective instructional approach for promoting learning. In fact, effective learning and teaching are directly related with the students' total opportunities of engagement and active learning [18–20].

The most extensive classroom response system is clicker, a small device that beams a radio-frequency signal to a receiver attached to the professor's computer, allowing students to become an active element in the lecture, and professor to track their progress based on multiple-choice questions [14–17, 21]. These go beyond typical recall questions for facts, and may include conceptual understanding questions, for example, asking students to classify, match characteristics with concepts, select the best explanation for a concept, or may include complex application questions, asking students to make a choice in

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a particular scenario, connecting contents with "real-world" situations, among others [18, 22]. One of the key features of clickers is the anonymity in the students' response, so even introverted or shy students who may fear to be judged by peer, can easily express their opinion and increase their participation.

However, clickers rely in one device per student, which can get relatively expensive in large classes. Plickers is a relatively new classroom response system which is intended to also provide immediate questions and feedback in class by using "paper-clickers". Unfortunately, this application has mostly been used in primary and secondary education [23], and tis utility in higher education remains unknown, in particular, when teaching in relatively large classrooms while teaching complex subjects such as neurosciences, based on the university student's fear of this field across countries [24].

The aim of this study is to illustrate the application a paper-based card responses system in neuroscience higher education, as an opportunity for improve formative learning, increase interaction and foster active learning in class.

Methodology

Participants

A medium class of the first year of the Degree in Medicine and a class of the second year of the Degree in Psychology were selected. Each with an average of 40 students each.

Instruments

Among all the potential applications, we selected Plickers, which can be downloaded from App Store for Apple devices or Play Store for Android devices. Its toolbar includes the following tabs: First, "library", where you can create questions to foster active learning, which can be stored and classified by classes; "reports", to check students's performance; "classes". "Live view" shows, in real time, the questions and answers being recorded. Finally, "cards", which basically consist on four-sided QR codes, one by student, ready to be printed and used by students to answer the questions asked (Fig. 1).

Design and procedure

An exploratory cross-sectional descriptive study was conducted.

First, the class roster is entered by the professor via the web-based application. Each student is assigned a unique number or name. Similarly, multiple-choice questions are directly typed in the web application, indicating the correct answer. Survey questions are also allowed, where no correct answer has to be identified. For example, to explore the perception of utility with the application. Then, the response cards are automatically generated by the application, ready to print in paper. Each response card consists on a four-sided QR code, one by student, used to answer the multiple-choice or survey questions which were displayed in class using a projector. Each response card contains the identification number or name for each student and the four answer options in small print to avoid been detected by peers.

When the question is displayed, every student holds their response card with the selected answer option (A, B, C or D) upwards. Then, the professor scanned the QR codes of all students simultaneously using the camera of his/her smartphone or table via the Plickers application.

While scanning, student responses are instantly detected by the web-based application and frequencies are displayed in real time as a bar below each answer option below the corresponding text, allowing both, professor and students professor to explore the degree in which students agree or not with each option for each question. The color code is as follows: green for right answers, red for wrong answers and blue, when the questions are set as survey, instead of multiple-choice questions. In addition, while scanning, the professor can privately see the name or identification number of every student and check if the answer is correct (coded in green) or not (coded in red).

After the scan, student responses are displayed in real time in a graphic bar below each answer option, so both, students and professor can explore the distribution of responses among the potential answers and keep track of which student has not answered yet. When the evaluation includes survey questions the color for answers is coded in blue. Furthermore, students could change their answers, and only the last choice is recorded after scanned. In addition, results are shown in real time on the professor smartphone or tablet, who controls if it is projected or not on the screen for the classroom.

Finally, as a precautionary measure on the part of the professor who is evaluating the students, if the results of the different questions are projected on the computer of the class, it is very important to always close the session (sign out), since otherwise the professor leaves, the students could enter the account and make any kind of modification. In addition, since response cards have a code (number) associated to every student, response cards should not be exchanged to keep track of each student response.

Results

In sum, the small amount of time involved in showing the multiple questions and scanning the response cards with Plickers is outweighed by a number of benefits for promoting students 'engagement and more active learning (Fig. 2).

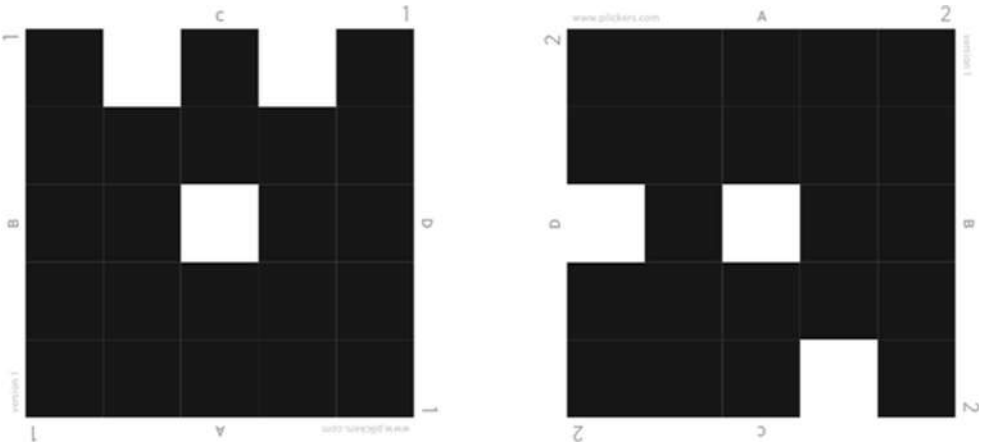

Fig. 1 Example of paper-based response cards used by students (identified by the number) to respond to the multiple choice questions (alternative answers corresponded with the small a, b, c and letters) by holding upwards the right alternative of answer

First, anonymity creates a safer classroom, encouraging student's participation in class, since students' responses using card-responses are kept unknown for the rest of the class, removing peer pressure for expressing their opinions even with sensitive ethical, legal, and moral questions, avoiding peer critiques or judgements. Furthermore, responses are displayed grouped by answer choice, so even if it is wrong, the responsibility of answering wrong is diffused and may even increase the bond between students during the learning process.

Second, it offers a digital feedback system in real time, so the professor has the opportunity to poll and visually track the degree of comprehension or misconceptions about complex neuroscience-related contents in real time, providing an opportunity to adjust or review the class. For example, the score sheet (Fig. 3) displays distribution of answers among the different options, which helps to identify potential misunderstandings based on wrong options highly selected. This means that it would be necessary to adjust the lecture "on the fly" or open class-wide discussions, which can be a challenge for some professors.

Third, the use of paper response-cards, provide an opportunity for breaking, the monotony of traditional class, even in classrooms with a large number of students, increasing interactivity, without rely on expensive clicker devices, minimizing the costs, addressing some of the major drawbacks of previous response systems, economic costs and complexity. This is particularly important when teaching complex contents in higher education to maintain student's attention during a lecture, since attention decreases after approximately 15 min of passive listening, extending the level of engagement for every student beyond the ones that raise their hand.

Discussion

Plickers provides an opportunity to increase interaction with students enhancing engagement and active learning at multiple levels, ranging from keep track of attendance to formative assessment by checking students understanding of key points in class with the purpose of providing real time information

Fig. 2 Visualization from the professor smartphone while scanning students QR response cards

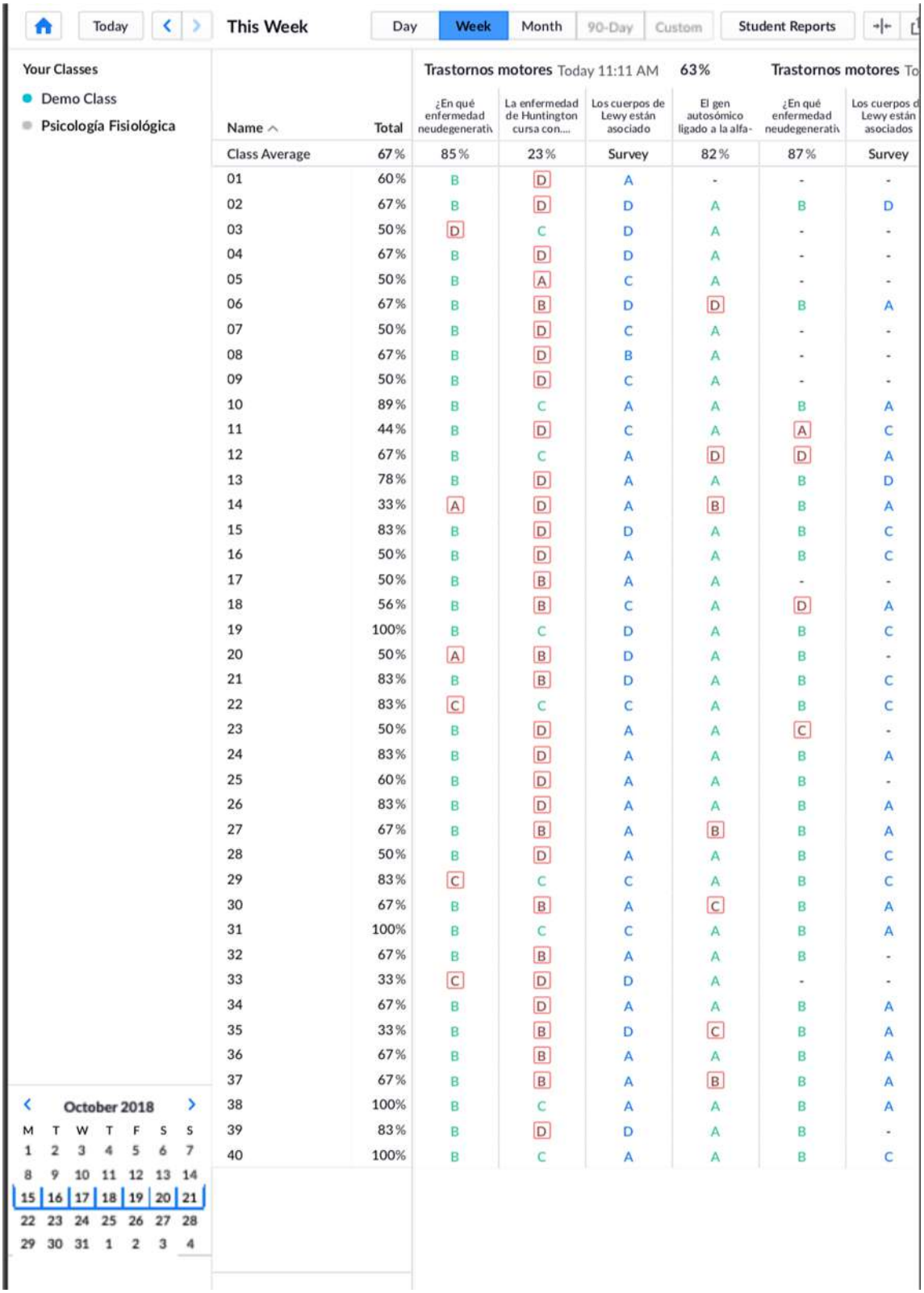

Fig. 3 Scoresheet with the distribution of selected answers for each item

about the learning progress to both, professor and students [8, 10]. This information can be used for revisiting or clarifying some concepts in response to students' feedback in real-time. This is especially important in relatively large groups [9, 10, 18]. Indeed, this application becomes an instructional method also in higher education [10–12, 22].

Even if learning outcomes do not directly improve, it provides opportunities for keeping the attention and flow of the class needed for formative assessment. Consistent with previous studies, our students reported a positive reaction of this application [11, 12, 24]. This response systems seems to increase both, the level of engagement of the class in check their students' understanding of complex concepts related with neurosciences [13, 25, 26].

The main drawback is the limitations of the free version. The maximum number of questions per class is 4 and the maximum number of students is 40. Number of responses are forced to 4. An alternative open-source solution is needed to overcome these limitations. Finally, it is important remember that technical problems can occur, and the utility of this classroom response system is based on the effectiveness of multiple-choice questions, which can be challenging to elaborate.

Future research should explore the empirical support for its use in controlled settings, measuring the impact of this response card system by itself or in comparison with other applications. In general, other technology-based applications mainly smartphones and tablets. This paper-based response system represents a paper-based and cost-efficient alternative to the use of traditional clicker response systems. It eliminates the need for professors to collect student response data on paper which are slow and can easily get lost [26]. Furthermore, students 'responses are stored online so the professor can get complete reports of students report to track their progress and monitorize the progress of the class. Students also can see the response results on the screen immediately while keeping the answers anonymous.

Overall, the small amount of time involved in showing the multiple questions and scanning the response cards with Plickers is outweighed by a number of benefits for promoting students 'engagement and more active learning. First, anonymity creates a safer classroom, encouraging student's participation in class, since students' responses using card-responses are kept unknown for the rest of the class, removing peer pressure for expressing their opinions even with sensitive ethical, legal, and moral questions, avoiding peer critiques or judgements. Furthermore, responses are displayed grouped by answer choice, so even if it is wrong, the responsibility of answering wrong is diffused and may even increase the bond between students during the learning process. Second, it offers a digital feedback system in real time, so the professor has the opportunity to poll and visually track the degree of comprehension or misconceptions about complex neuroscience-related contents in real time, providing an opportunity to adjust or review the class. For example, the distribution of answers among the different options helps to identify potential misunderstandings based on wrong options highly selected.

Conclusions

Overall, the use of this application provides an opportunity to foster student's engagement and active learning in neuroscience education. It provides an opportunity to increase the interaction with students enhancing engagement and active learning at multiple levels, ranging from keep track of attendance to formative assessment by checking students understanding of key points in class with the purpose of providing real time information about the learning progress to both, professor and students, so class adjustments can be implemented, such as revisiting or clarifying some concepts in response to the learning needs of the students, especially in relatively large groups.

The incorporation into the classroom of innovative teaching-learning methodologies, through the use of mobile devices by students, favors and stimulates the process of university education. These technological resources mixed with active learning and assessment methodologies improve the academic performance when the student submits to a continuous evaluation of the knowledge that is acquired. Therefore, the implementation of active methodologies requires good planning to guarantee an inclusive space for students that allows them to carry out their activities and express their knowledge in a group and individual way.

One of the great advantages of this type of activity is that the professor can detect the students who stand out most in their learning compared to those who are slower; In this way the professor can implement the strategies that he considers appropriate to level the learning of the different students.

Compliance with Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Verbal informed consent was obtained from all individual participants included in the study.

Conflict of Interest All authors, Pablo Ruisoto and Juan A Juanes, declare that they have no conflict of interest.

References

1. Harden, R. M., and Crosby, J. R., The professor and changes in medical education. *AMME Education Guide* 20:3–5, 2000.
2. Mitre, S. M., Batista, R. S., Mendonça, J. M. G., Pinto, N. M. N., Meirelles, C. A. B., and Porto, C. P., Metodologias ativas de Ensino aprendizagem na formação profissional em saúde: debates atuais. *Ciências e saúde coletiva* 13:2133–2144, 2008.
3. Caldwell, J. E., Clickers in the large classroom: Current research and best-practice tips. *CBE Life Sciences Education* 6:9–20, 2007.

4. Garcia-Ramirez, J. M., Las Tecnologías de la Información y la Comunicación, TIC, en la educación universitaria. *Andaluciaeduca* 76:77–84, 2012.
5. Briz-Ponce, L., and Juanes-Méndez, J. A., Mobile devices and apps, characteristics and current potential on learning. *Journal of Information Technology Research* 8:26–37, 2015.
6. Briz-Ponce, L., Pereira, A., Carvalho, L., Juanes-Méndez, J. A., and García-Peñalvo, F. J., Learning with mobile technologies – Students' behavior. *Comput. Hum. Behav.* 72:612–620, 2017.
7. Poirier, C. R., and Feldman, R. S., Promoting active learning using individual response technology in large introductory psychology classes. *Teach. Psychol.* 34:194–196, 2007.
8. Howell, D. D., Tseng, D. C., and Colorado-Resa, J. T., Fast assessments with digital tools using multiple-choice questions. *Coll. Teach.* 65:145–147, 2017.
9. Blood, E., Effects of student response systems on participation and learning of students with emotional and behavioral disorders. *Behav. Disord.* 35:214–228, 2010.
10. Clunies-Ross, P., Little, E., and Kienhuis, M., Self-reported and actual use of proactive and reactive classroom management strategies and their relationship with teacher stress and student behaviour. *Educ. Psychol.* 28:693–710, 2008.
11. Heaslip, G., Donovan, P., and Cullen, J. G., Student response systems and learner engagement in large classes. *Act. Learn. High. Educ.* 15:11–24, 2014.
12. Malanga, P. R., and Sweeney, W. J., Increasing active student responding in a university applied behavior analysis course: The effect of daily assessment and response cards on end of week quiz scores. *J. Behav. Educ.* 17:187–199, 2008.
13. Stowel, J. R., and Nelson, J. M., Benefits of electronic audience response systems on student participation, learning, and emotion. *Teach. Psychol.* 34:253–258, 2009.
14. Trees, A. R., and Jackson, M. H., The learning environment in clicker classrooms: Student processes of learning and involvement in large university-level courses using student response systems. *Learn. Media Technol.* 32:21–40, 2007.
15. Lantz, M., The use of clickers in the classroom: Teaching innovation or merely an amusing novelty? *Comput. Hum. Behav.* 26:556–561, 2010.
16. Mayer, R. E., Stull, A., DeLeeuw, K., Almeroth, K., Bimber, B., Chun, D., Bulger, M., Campbell, J., Knight, A., and Zhang, H., Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemp. Educ. Psychol.* 34:51–57, 2009.
17. Morling, B., McAuliffe, M., Cohen, L., and DiLorenzo, T. M., Efficacy of personal response systems ("clickers") in large, introductory psychology classes. *Teach. Psychol.* 35:45–50, 2008.
18. Haydon, T., Conroy, M. A., Scott, T. M., Sindelar, P. T., Barber, B. R., and Orlando, A. M., A comparison of three types of opportunities to respond on student academic and social behaviors. *J. Emot. Behav. Disord.* 18:27–40, 2010.
19. Hardesty, S. L., McIvor, M. M., Wagner, L. L., Hagopian, L. P., and Bowman, L. G., A further evaluation of response cards: Teaching direct care staff basic behavioral principles. *J. Organ. Behav. Manag.* 34:156–164, 2014.
20. Harper, B. E., 'I've never seen or heard it this way!' Increasing student engagement through the use of technology-enhanced feedback. *Teaching Educational Psychology* 3:1–8, 2009.
21. Patry, M., Clickers in large classes: From student perceptions towards an understanding of best practices. *International Journal of the Scholarship of Teaching and Learning* 3:1–11, 2009.
22. Haydon, T., and Hunter, W., The effects of two types of teacher questioning on teacher behavior and student performance: A case study. *Educ. Treat. Child.* 34:229–245, 2011.
23. McCargo, M. G., The effects of Plickers as response cards on academic engagement behavior in high school students (master thesis). Hattiesbrug, Mississippi, USA, 2017.
24. Solorzano, G. E., and Józefowicz, R. F., Neurophobia a chronic disease of medical students. *Neurology* 85:116–117, 2015.
25. Shapiro, A., An empirical study of personal response technology for improving attendance and learning in a large class. *Journal of the Scholarship of Teaching and Learning* 9:13–26, 2009.
26. Shaffer, D. M., and Collura, M. J., Evaluating the effectiveness of a personal response system in the classroom. *Teach. Psychol.* 36: 273–277, 2009.