Usability and Reliability Data Relative to the Use of Clickers to Support the Computer Science Peer Instruction (CSPI) Approach

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Abstract. In previous work we implemented and compared three learning approaches in a Computer Science introductory programming course (CS1): traditional lectured-based learning; problem-based learning; and Peer Instruction (PI). The study also pointed out guidelines to support a customized and a more effective PI-based approach to the Computer Science environment, defined as CSPI (Computer Science Peer Instruction). In this work we present data related to a first use of CSPI in some classes of a CS1 course taught in Python language (MC102). Specifically, this study presents the usability and reliability data relative to the use of clickers (student response systems) to support the CSPI approach. As the research is still in development, we plan to discuss the CSPI approach, its educational impact, and assessment in future works.

Keywords: Peer Instruction; CS; CS1; Python; Computer Science; Clickers; Usability; Reliability

1. Introduction

This report presents an ongoing work related to the development and assessment of the Computer Science Peer Instruction (CSPI) methodology, created to support the Peer Instruction (PI) approach to Computer Science introductory programming courses (CS1 courses).

As explained in our previous work [1]:

> *"PI is an active learning technique introduced and popularized by Eric Mazur [2]. Initially used in the Physics domain, it has expanded to other areas, enjoying popularity among STEM faculty members, including CS courses [3]. As explained by Crouch&Mazur [1], PI engages students through activities (conceptual questions) during the class, allowing the instructor to identify any misunderstandings or learning issues among the students regarding the core concepts taught. In a typical PI class, the instructor only continues to the next planned topic if at least 75% of the students have correctly answered the conceptual questions. Otherwise, students are encouraged to discuss the answers among themselves, trying to convince colleagues that their point of view is correct. The PI technique is usually supported by technological devices, such as clickers or smartphone apps."*

In previous work [1] we implemented and compared three learning approaches in a CS1 course[1]: traditional lectured-based learning; problem-based learning, and PI. We focused on assessing and analyzing how students' motivation and learning process were affected, as well as how difficult it was for instructors to prepare classes and how much time they expended when doing so.

Related to the PI, in the previous work [1] we employed the technique through the use of smartphones (Poll Everywhere tool[2]). The study also pointed out guidelines to support

[1] CS1 stands for "Computer Science 1", the first mandatory programming course in a Computer Science major. The study presented in the previous work [1] was held at the University of Campinas (Unicamp), in the 2017 second semester, in the *MC102: Algorithms and Computing Programming* course

[2] Available at: https://www.polleverywhere.com/ Accessed: May 2018

a customized and more effective PI-based approach to the Computer Science environment (defined as CSPI).

In this work we present data related to a first use of CSPI in some classes of a CS1 course. Specifically, this study focuses on the **usability and reliability data** of the clickers to support the CSPI approach. As the research is still in development, we plan in future works to discuss the data obtained and presented on this study, as well as the CSPI approach, its educational impact and assessment of its effectiveness.

Figure 1 illustrates the CSPI research steps:

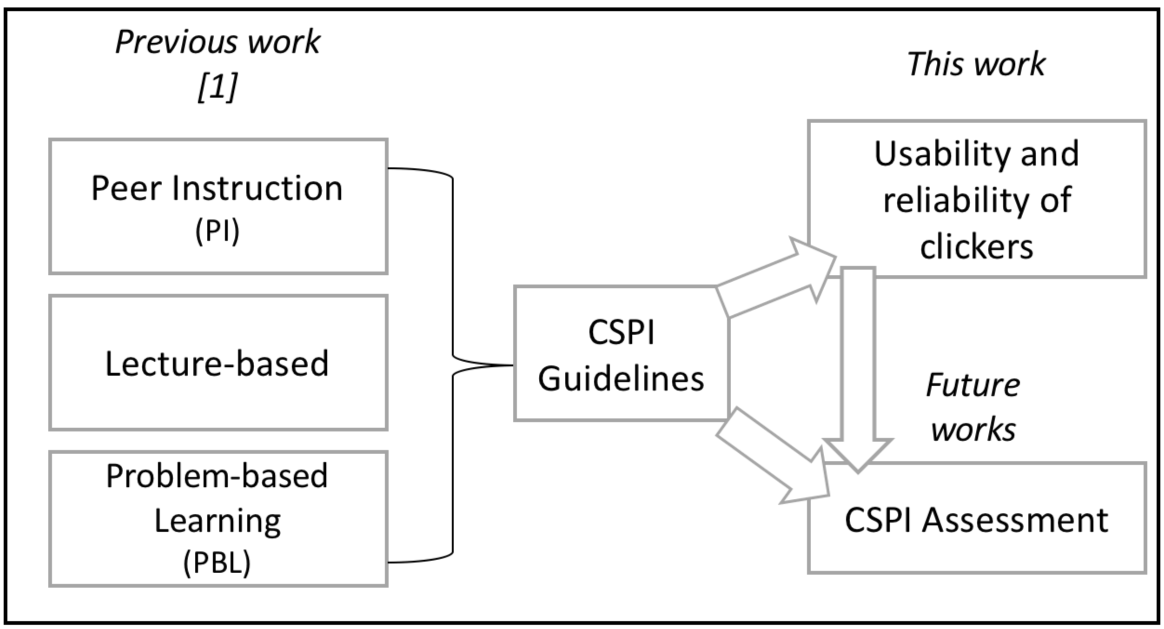

Figure 1. CSPI research steps. The current study presents data relative to the usability and reliability of clickers to support the CSPI approach

This technical report is organized as follows: section 2 presents the study methodology; section 3 presents the outcomes (quantitative and qualitative data related to the usability and reliability of the clickers); and in section 4 the next steps for this research. This document also has 2 appendixes: Appendix A describes a CSPI class from an outsider's view (a graduate student) combined with the instructor's view and; Appendix B shows the feedback questionnaire answered by the students.

2. Methodology

This study was conducted in the CS1 course “MC102 – Algorithms and Computer Programming” of the University of Campinas (Unicamp), in the start of the 2018 first semester. The course had 132[3] students enrolled when it began and was organized as follows: 2 theoretical and 2 practical classes per week, with duration of 1 hour and 40 minutes each.

The theoretical classes, taught by a postdoctoral researcher, employed the CSPI approach using clickers as a technological support device. All enrolled students had the same theoretical classes (students were not divided into subgroups). For the practical classes students were divided into 4 groups (around 33 students per group), with each group having separate classes in a laboratory, being advised by TAs.

At the end of the 8th class the students answered a questionnaire (see Appendix B) related to the usability and reliability of the clickers employed in the theoretical classes. By this class, they had so far answered a total of 58 multiple-choice questions with iClickes+ devices.

The course programming language was Python, and the topics covered until the 8th class had been: variables, basic types and objects, Boolean expressions, conditional statements and loop commands. Also, a graduate student observed a theoretical class (the 8th class), analysing how CSPI was conducted. The report of this student's experience, complemented by the instructor's vision, can be found in the Appendix A of this document.

The following sections present the materials used (see section 2.1) and the steps of the CSPI approach employed throughout this study.

2.1 Materials

A set of 40 iClickers+ (iClicker brand[4]) was shared by the students. The instructor, in turn, had an “instructor remote” that enabled him to activate specific software features, such as the option to display a consolidated chart with the answers submitted by the students or

[3] The MC102 course is indeed a coordinated discipline, offered to all undergraduate students enrolled in one of the university's STEM programs. Therefore, this study was carried out with a specific class (“4567”), composed mostly of students who had already taken – but not successfully completed – the course in previous semesters.
[4] Available at: https://www.iclicker.com/ Accessed in: May 2018

advance the presentation to the next slide. All iClickers (students and instructor) communicated with the instructor's notebook (a Macbook pro 15-inch model – late 2015) through an iClicker base. The instructor's notebook, connected to an external projector, ran two programs: a PowerPoint presentation (with the theoretical content and the exercises) and the iClicker Classic software (version 7.17.0, Build 121). A detailed description of how the class content was organized and how the questions were designed will be included in future work.

Figure 2 shows the devices used in this study: a student iClicker+ (Figure 2a); an instructor iClicker+ (Figure 2b); and the iClicker base (Figure 2c).

2a

2b

2c

Figure 2. iClicker devices used in this study: student iClicker+ (Figure 2a); instructor iClicker+ (Figure 2b); and iClicker base (Figure 2c).

2.2 CSPI Steps

Table 1 details the 5 steps (S0 to S4) of the CSPI approach employed in this study:

Step	Description
S0	• At the start of the class, the instructor distributes the clickers to students. Students are encouraged to share a clicker with their colleagues, thus working in pairs or groups of 3 people. The instructor does not intervene in this process, so it is possible that bigger or smaller groups are formed (*e.g*. groups of 4 students sharing a single clicker or students working alone).
S1	• Traditional class. • Theoretical concepts presented through PowerPoint slides.
S2	• Proposal of a question to be solved by the students. • Countdown timer activated in the iClicker software, limiting the resolution time to 4 minutes. • Resolution process organized into three slides: ○ **Slide 1:** Shows the question statement. The question's choices are not displayed. This slide is shown for 1 minute (*i.e*. until the countdown reaches the 3-minute mark). Students are encouraged to think individually about how to answer the question and what the correct answer might be. Although students are allowed to submit their answers, it does not make sense for them to do so at this point, as they have not yet been shown the alternative answers.

	○ **Slide 2:** Same as previous slide, except the question's choices are displayed. Students are encouraged to discuss among their peers the possible answers and, once an agreement is reached, submit their answer. This slide is shown until one of the following situations happens: a) the countdown timer expires (reaches the 0:00 mark) or; b) about 90% of the students have submitted their response. In the latter situation, before proceeding to slide 3 the instructor asks the students: "Anyone else want to answer this exercise?" ○ **Slide 3:** Reveals the correct answer to all students. The instructor also presses a button on his/her clicker[5], allowing the iClicker software to show a bar graph with the students' answers to the current question. The instructor then continues their class based on the number of correct answers: ▪ > 75%: the instructor gives a simple explanation (or no explanation at all) about the exercise. ▪ >= 40% and <= 75%: the instructor gives a thorough explanation about the question and its solution. ▪ < 40%: the instructor explains again the theoretical content (step S1) related to the current question and then gives a thorough explanation about the question and its solution.
S3	Repetition of step S2 until there are no more questions related the current theoretical concept.
S4	Presentation of new theoretical concepts (start step E1 again).

Table 1. CSPI 5 steps

[5] The iClicker+ instructor's clicker has some special features. For example, it allows the instructor to control the presentation (next or previous slides) or to show/hide a table with the student's answers related to the current exercise.

3. Outcomes

At the end of the 8th class of the course, the instructor asked the students present in the class (N = 65) to answer a questionnaire (see Appendix A) to assess their confidence when using the clickers in the CSPI classes. The questionnaire, composed of 6 questions, was organized as follows:

- Multiple-choice question *(quantitative data)*: Question 1
- Likert multiple-choice question *(quantitative data)*: Questions 2, 3, and 4
- Open-ended questions *(qualitative data)*: Questions 5 and 6

The students took around 15 minutes to answer the questions. The following sections (3.1 to 3.6) present the data collected through this questionnaire.

3.1 Question 1

Figure 3 shows the students' answers to the following question: *"Most of the time, during classes with clickers, you:"*

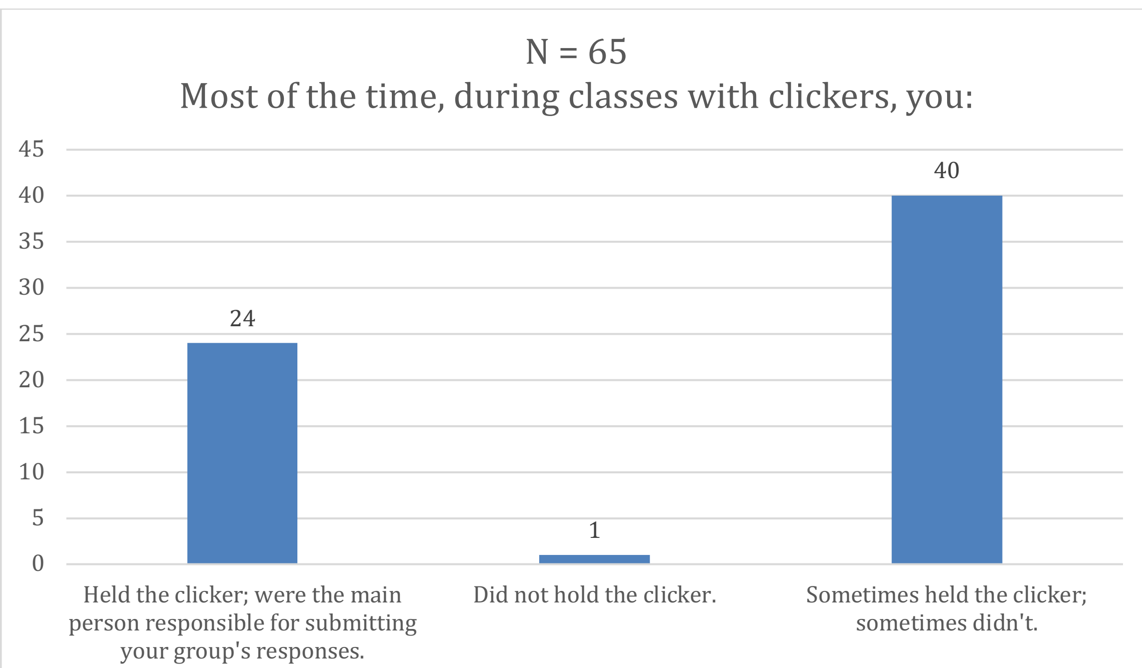

Figure 3. Multiple-choice question (3 possible choices) concerning whether or not the student held the clicker in the class

3.2) Question 2

Figure 4 shows the students' answers to the following statement: *"In a same question, I, or someone in my group, pressed a clicker response button more than once to confirm whether the response had been correctly submitted/received by the system"*.

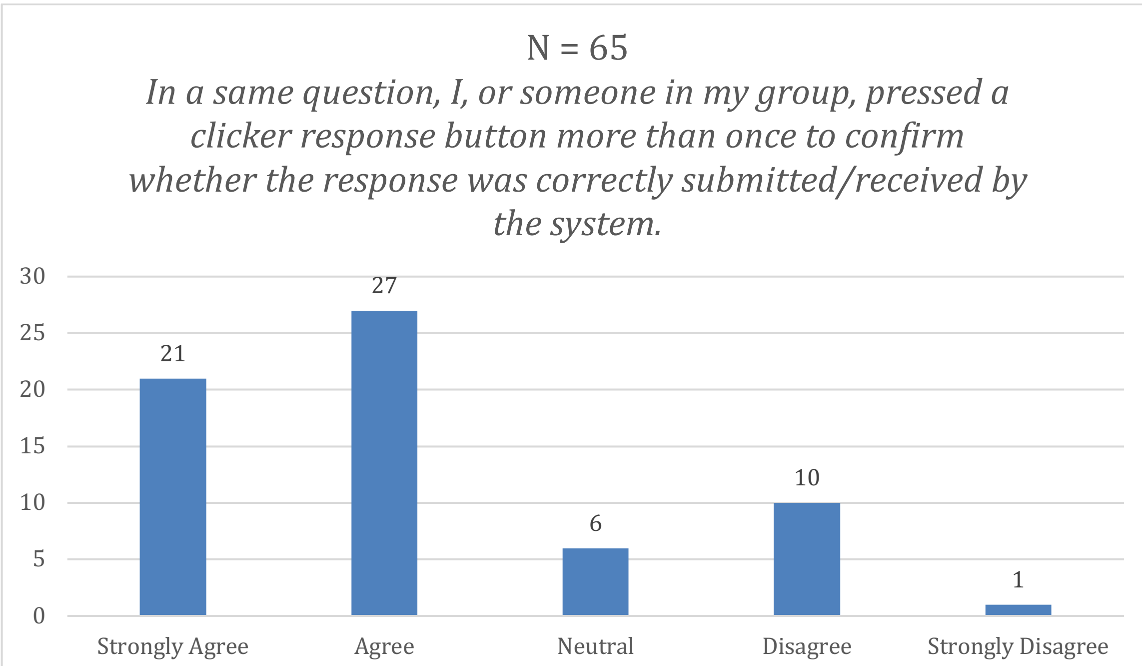

Figure 4. Likert-scale multiple-choice question related to whether the students submitted the same answer more than once to confirm that the response had been correctly received by the system.

2.3) Question 3

Figure 5 shows the students' answers to the following statement: *"After submitting a response (pressing a clicker response button) it is possible to be 100% sure that that response has been received and processed by the system"*.

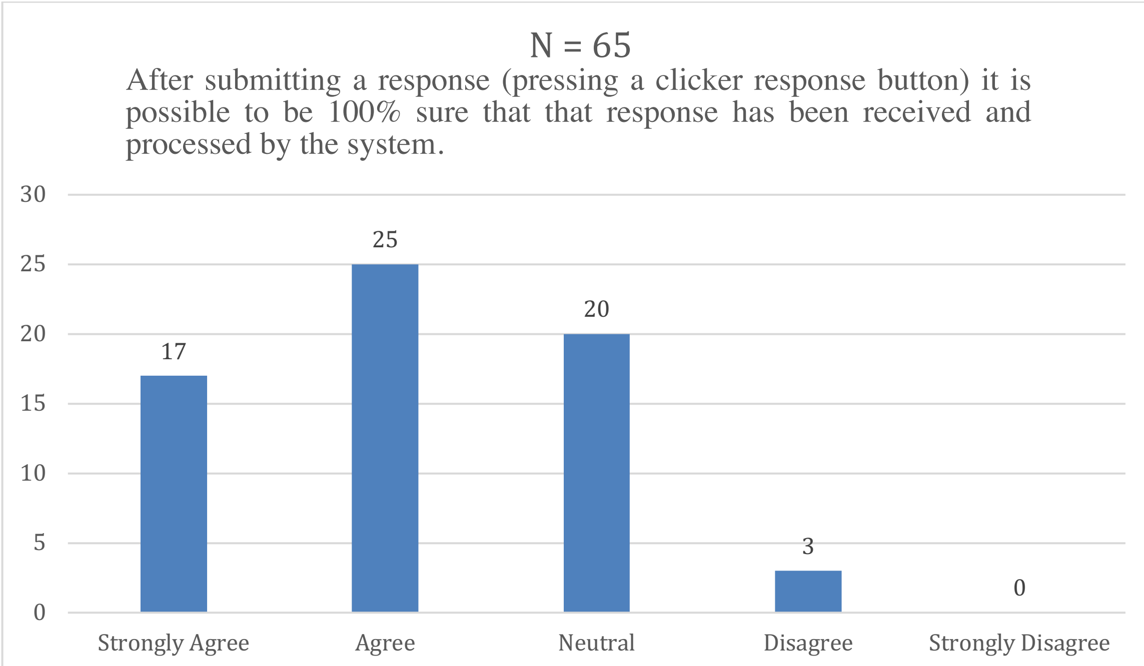

Figure 5. Likert-scale multiple-choice question related to whether the students are confident their response has been correctly received by the system

3.4 Question 4

Figure 6 shows the students' answers to the following statement:

"To confirm that the clicker was working, I, or someone in my group, used some workaround, such as:

- *Submitting a response before the teacher opens the available options.*
- *If possible, submitting a different answer from the majority to check whether the submissions were being correctly received and processed.*
- *Waiting for the other students to submit the answers, making it simpler to verify whether the increase in the number of submissions was caused by my group's submission."*

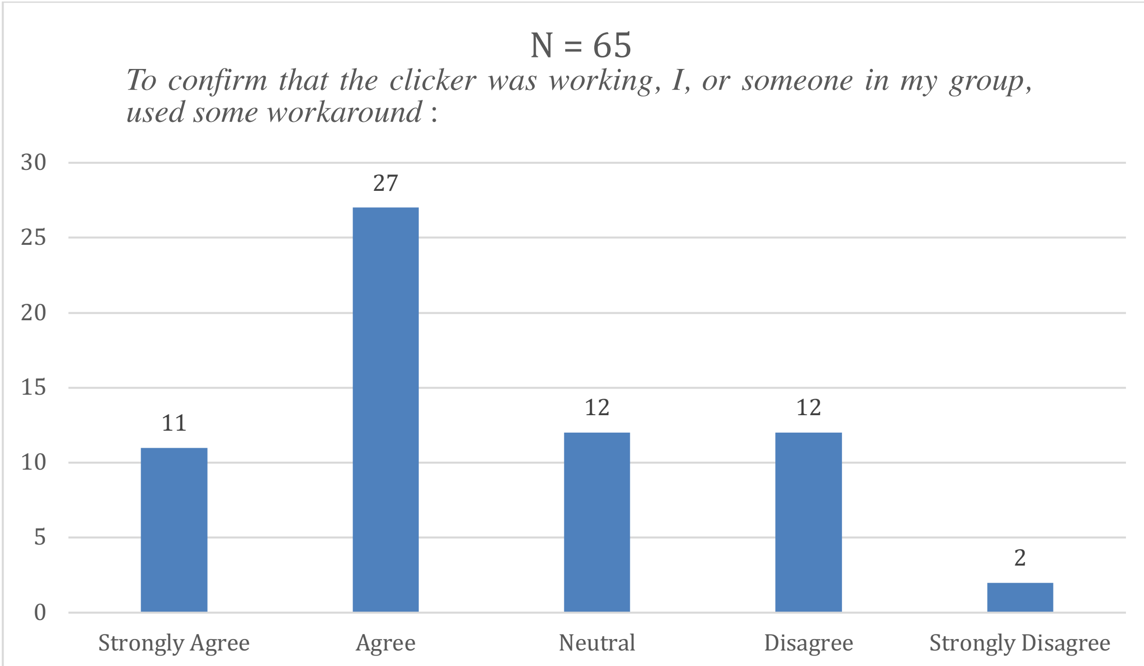

Figure 6. Likert-scale multiple-choice question related to whether the students used some workaround (*e.g.* submit the answer before the others) to be sure their response had been correctly received by the system.

3.5 Question 5

Table 2 shows the answers (N= 18) for the following open-ended question: *"Suggestions on how to improve confidence that your response was correctly received by the system."* The answers were organized in the following groups: lights; batteries; miscellaneous; use of ID numbers of the clickers to identify students; individual testing; slide notification; and no suggestion.

Group	Description
Lights	• The light for the chosen alternative remains on. • If possible, the light color on the pressed button should change, as this would make it easier to verify that the response has been delivered. • Clicker light indicating the correct answer stays on until the response is evaluated.
Batteries	• I think that if the clickers' batteries were always checked (not failing), we would be more certain that the signal had been sent. • Always keep the batteries up to date. Test before class.
Miscellaneous	• Lock clickers as a way of blocking a second response.
Clicker IDs to identify students	• Add a table next to the responses with the clickers IDs who submitted each alternative. • Yes, identify the ids of clicker in the responses. • Identify clickers so that you know which clicker voted for which response. • Something appears on the slide with the clicker ID from which the response was sent, such as a list. • Display onscreen the vote tallies and clicker IDs related to each response.
Individual testing	• Conduct an individual round of testing. • Suggest that each clicker holder submit their chosen response one by one, checking whether their answers have been submitted.

Slide notification	• A notification or signal on the slide that confirms the response has been received. • Use a feed that shows the number of clickers that submitted a response.
No suggestion	• I believe we are already convinced that clickers work. • Fully reliable • No suggestion, since the light when you press the button and the onscreen counter are sufficient.

Table 2. Categorization of Open-ended answers related to suggestions on how to improve students' confidence when using clickers.

3.6 Question 6

Table 3 shows the answers (N=12) for the following open-ended question: *"Other comments related to the use of clickers and how confident you are using this device:"*

- I think it is reliable.
- Best MC102 *(the CS1 course initials)* class in the world!
- Since it is possible to check the number of submissions received, and knowing how many clickers were distributed to students, it is easy to identify any problems in the submission of the answers.
- Very reliable. I liked this method.
- I loved it
- Everything is fine with the current state.
- Super didactic the use of clickers.
- I believe my answer has been submitted because the light corresponding to my alternative turns on.
- Sometimes some clickers turn off by themselves and we have to press the power button or open the clicker's cover, rotate the batteries and press the power button again.

• Shorten the time for submitting answers. • I think it is a good idea to use the device, even when in shared use, as it stimulates the development of learning. • Perfect instructor.

Table 3. Additional comments and suggestions related to the student's confidence when using clicker.

4. Future Work

The next steps on this research relates to the analysis of the data presented on this study, and also the assessment of the CSPI methodology and its impact on teaching and learning. We plan to evaluate CSPI in the middle of the semester, adjusting the methodology to the student's and instructor's needs, as well as taking the usability and reliability issues pointed out in this study into consideration.

5. Acknowledgments

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6. References

[1] CACEFFO, R.; GAMA, GUILHERME; AZEVEDO, R. 2018. Exploring Active Learning Approaches to Computer Science Classes. In Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE '18). ACM, New York, NY, USA, 922-927. DOI: https://doi.org/10.1145/3159450.3159585

[2] CROUCH, C.; MAZUR, E. 2001. Peer Instruction: Ten years of experience and results. American Journal of Physics 69, 9 (2001), 970–977. https: //doi.org/10.1119/1.1374249 arXiv: http://dx.doi.org/10.1119/1.1374249

[3] LIAO, S. GRISWOLD, W.; PORTER, L. 2017. Impact of Class Size on Student Evaluations for Traditional and Peer Instruction Classrooms. In Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education (SIGCSE '17)

Appendix A – CSPI class from an outsider observer (a graduate student) combined with the instructor's view

"The present text summarizes a class, held on March 26, 2018, of the MC102 – Algorithms and Computer Programming, focusing on the students' behavior and in the methodology applied by the teacher.

Before starting the class, the teacher explained the clickers were in a box under his desk and the students were free to get them. As the number of available clickers was 40 but there were 123 enrolled students, the instructor advised the students to get one clicker to be shared among 2 or 3 students. As there were around 80 students in the class, only part of the clickers (around 20) were retrieved by the students. Then the instructor asked who would like to get a clicker, redistributing the remaining clickers to the students who raised their hands.

The instructor started the class by explaining some examples of iterations (loops) in Python. One student asked a question, which was answered by the instructor. The instructor then continued to the next topic, describing the concept and providing an example (algorithm) related to accumulating variables.

Then the instructor started the questions phase, presenting some questions that should be answered by the students through the clickers. Each question was presented in a sequence of 3 slides: a) a slide with a question statement (usually "What will be printed by the following program?") and a code fragment; b) a slide with the same content of the previous, plus a table mapping the letters A to E to 5 possible answers; and c) a slide with the same content as the previous one, but with the correct answer highlighted. After showing the first slide, the instructor started a 4-minute countdown in the iClicker software. When the countdown was near the 3-minute mark, the instructor proceeded to the next slide, allowing the students to check their current answers against the available choices and then submit the one they considered to be correct.

Finally, when the countdown was over, or when around 35 students had submitted their vote (the number of currently submitted answers was public, displayed in the iClicker software), the instructor proceeded to the final slide, in which the correct answer was displayed. Then a chart generated by the iClicker software was shown, revealing all students' choices. The instructor then explained the correct answer, also asking the students whether they had any questions about it. The instructor took more time explaining questions that had had fewer correct answers.

During the resolution of the exercises, some conversations among students took place. A group of three students talked the whole class about domestic matters (cooking, relationship with boyfriend, clothes that like to use, and so on). This group answered the exercise, but did not focus on the teacher's explanation of the correct answer. Another group of students commented among themselves that they already knew the subject well and that the issues raised by the teacher were very trivial. An explanation for this behavior could be that the topic covered in the class was too basic for these students. The reason for this can be that around two-thirds of the enrolled students had already taken the course in previous semesters, having withdrawn or failed.

Some students also commented among themselves that their solution was different from the one presented by the instructor. However, they did not share their position with their peers at any point during the class.

Most of the students carefully followed the class, using the clickers as planned and also discussing among themselves the options to be chosen. The students seemed motivated by the use of the device.

Finally, at the end of the class, the instructor asked the students to answer a questionnaire related to the clickers, focusing on the feedback and reliability of submitting answers through the device."

Appendix B – Feedback Questionnaire

This appendix presents the questionnaire answered by the students in this study[6].

This questionnaire is anonymous. It refers to all classes of this course–not just today's class.

1) Most of time, during classes with clickers, you:

	Held the clicker; were the main person responsible for submitting your group's responses.
	Did not hold the clicker.
	Sometimes held the clicker; sometimes didn't.

2) Consider the following statement and check the choice that best fits your opinion: *"In a same question, I, or someone in my group, pressed a clicker response button more than once to confirm whether the response had been correctly submitted/received by the system".*

	Strongly Agree
	Agree
	Neutral
	Disagree
	Strongly Disagree

[6] The original questionnaire was in Portuguese language. On this Appendix we present the translated version (from Portuguese to English). The outcomes presented on this work were also translated.

3) Consider the following statement and check the choice that best fits your opinion: "*After submitting a response (pressing a clicker response button) it is possible to be 100% sure that that response has been received and processed by the system"*.

	Strongly Agree
	Agree
	Neutral
	Disagree
	Strongly Disagree

4) Consider the following statement and check the choice that best fits your opinion:

"To confirm that the clicker was working, I, or someone in my group, used some workaround, such as:

- *Submitting a response before the teacher opens the available options*
- *If possible, submit a different answer from the majority to check whether the submissions were being correctly received and processed.*
- *Waiting for the other students to submit the answers, making it simpler to verify whether the increase in the number of submissions was caused by my group's submission."*

	Strongly Agree
	Agree
	Neutral
	Disagree
	Strongly Disagree

5) **Suggestions** on how to improve confidence that your response was correctly received by the system.

6) Other comments related to the use of clickers and how confident you are using this device: