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A dialogue between Vygotsky's learning theory and peer instruction in Astronomy classes

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Abstract. Active learning methodologies have been used to teach science, technology, engineering, arts and mathematics at higher education institutions in several countries. We report the results of using peer instruction in an Astronomy undergraduate course taught at a research university in Brazil. The course syllabus covered topics on astrometry and celestial mechanics at an introductory level and was offered in the second semester of 2018. In order to better investigate the effect of the interaction among students, we have asked them to talk to their peers after the first poll regardless of the outcome. We have then analyzed the outcomes of all peer instruction polls, before and after student interaction, as well as the course evaluation questionnaires answered by the students at the end of the semester. From these analyses we were able to establish an approximation between peer instruction and some key elements of Vygotsky's social interactionist theory.

Keywords. Active learning, Astronomy education, Peer instruction, Vygotsky's social interactionist theory.

1. Introduction

Peer instruction is a student-centered active learning methodology developed by Eric Mazur at Harvard University in the early 1990s (Mazur 1997) that has been successfully used in science, technology, engineering, arts and mathematics (STEAM) classes since then (e.g. Crouch & Mazur 2001, Lenaerts *et al.* 2002, Lucas 2009, Wood 2009, Zingaro & Porter 2014). There is robust evidence that this methodology enhances students' understanding (e.g. Smith *et al.* 2009) and reduces dropout rates (e.g. Watkins & Mazur 2013).

Turpen & Finkelstein (2009) showed that the way peer instruction is implemented by instructors is not unique. Despite of these variations, a typical peer instruction session usually comprises of seven steps (Mazur 1997, Vickrey *et al.* 2015):

(*a*) Question posed
(*b*) Students given time to think

(*c*) Students record individual answers
(*d*) Students convince their neighbors (peer discussion)
(*e*) Students record revised answers
(*f*) Feedback to instructor: tally of answers
(*g*) Instructor's explanation of correct answer

Since the interaction among the students plays a pivotal role in this methodology, the main objective of this research was to perform an approximation between peer instruction and Vygotsky's social interactionist theory (Vygotsky 1980) using data collected in an Astronomy course taught at Universidade Federal de Itajubá, a research university in Brazil.

In order to perform this semester-long investigation, a new design for the course was implemented in 2018 so that peer instruction could be used throughout the semester. Given the encouraging results we have found, we intend to keep this approach for future offerings.

In the next session we provide a brief overview of the course, after which we present and discuss the implications of this research.

2. Overview

The syllabus of the Astronomy course covers topics of astrometry and celestial mechanics at an introductory level. It was taught along 16 weeks in the second semester of 2018 for undergraduate students, most of them majoring in meteorology, physics or chemistry. Forty-seven students enrolled in the course, but nine of them withdrew before the end of the semester, so the dropout rate was 19%.

Each week the students had a pre-class session on a virtual learning environment, followed by two 110-minute long sessions on campus. During on-campus sessions the students had hands-on activities, problem solving group tasks and peer instruction classes, but no traditional lectures were given.

In peer instruction sessions, a multiple-choice conceptual question was posed to the students, who were instructed to write their answers in individual paper cards, after having some time to think. Then the instructor asked them to discuss their choice with a peer who had chosen a different alternative. After a few minutes, they were asked to answer again the same question in another paper card. The instructor followed the strategy described by Smith *et al.* (2011), so that in each class the students were asked to answer six multiple-choice questions about the same subject and they voted in both polls, regardless of the score of the first poll.

At the end of the semester, the students answered a questionnaire designed to provide a feedback on their perception about the course. The questionnaire had ten multiple-choice and five open-ended questions. We have analyzed not only the quantitative results from the polls, but also the qualitative results found in the students' answers to the questionnaire. In this paper we present some of these results and a full description of the data analysis can be found in De Paula *et al.* (2020).

3. Implications

Figure 1 shows, for each question in which the students interacted with their peers, the overall score of the class on the second poll as a function of the score on the first poll. In 17 cases the score of the class increased after the interaction among the students. In two cases (shown in red) both scores were the same, while in one case (shown in green) the score on the second poll was lower than the first score. These results are consistent with the literature, as shown, for example, in the review paper by Vickrey *et al.* (2015).

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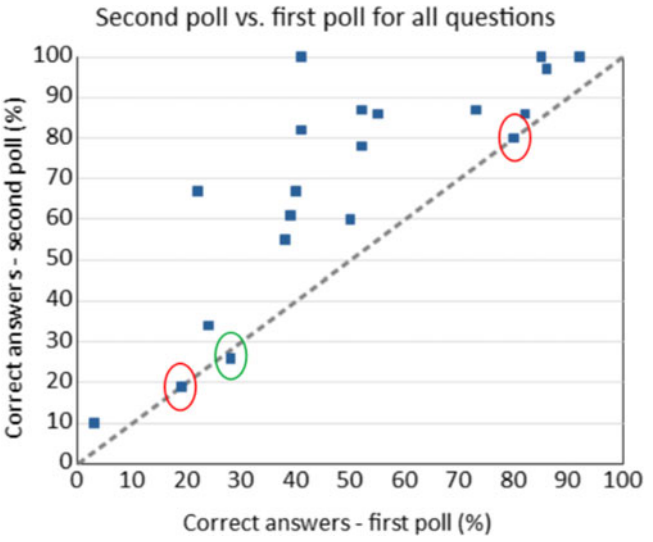

Figure 1. Second poll vs. first poll overall score for all peer instruction questions. Adapted from De Paula *et al.* (2020).

These results show that a large number of students who chose a wrong alternative in the first poll switched to the correct answer in the second poll. Under the framework of Vygotsky's social interactionist theory, we may consider that, for these students, the concept assessed by the question was within their *zone of proximal development*. Thus, in the first poll they could not figure out the right answer by themselves, but after interacting with their peers, they were able to answer the question correctly.

We should also note that peer instruction classes encourage the students to express their thoughts in words when they interact with their peers (Mazur 1997), which reminds us of Vygotsky's concepts of *language* and *cultural mediation* (Vygotsky 1986). Language plays a key role in his theory, since by verbalizing a conflict, the students find a way to solve the conflict under the mediation of their peers, who are the *more knowledgeable others* - another important concept of the theory.

After performing this quantitative analysis, we focused our attention on the questionnaire the students answered at the end of the semester. By analyzing the answers to the open-ended questions, we were able to identify other elements of Vygotsky's theory.

One student wrote:

> "This methodology, which requires us to answer the questions and then have a discussion with our peers, was essential for a better learning of the subject. When we talk to our colleagues, those who explain and those who listen to the explanation reach a better conclusion."

Yet another student wrote:

> "The multiple-choice questions were very important to our learning because we could check if we had really understood the subject, as well as being able to agree or disagree with our classmates."

Two key concepts of the social interactionist theory can be pointed out from these statements: the *social interaction* among the students and the use of *language* while interacting with their peers.

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References

Crouch, C.H., & Mazur, E. 2001, *Am. J. Phys.*, 69, 970
De Paula, J., Figueiredo, N., & Ferraz, D.P.A. 2020, *Cad. Bras. Ens. Fis.*, 37, 127
Lenaerts, J., Wieme, W., & Van Zele, E. 2002, *Eur. J. Phys.*, 24, 7
Lucas, A. 2009, *PRIMUS*, 19, 219
Mazur, E. 1997, *Peer Instruction: A User's Manual* (Upper Saddle River: Prentice-Hall)
Smith, M.K., Wood, W.B., Adams, W.K., Wieman, C., Knight, J.K., Guild, N., & Su, T.T. 2009, *Science*, 323, 122
Smith, M.K., Wood, W.B., Krauter, K., & Knight, J.K. 2011, *CBE-Life Sci. Educ.*, 10, 55
Turpen, C., & Finkelstein, N. 2009, *Phys. Rev. Spec. Top. Phys. Educ. Res.*, 5, 20101
Vickrey, T., Rosploch, K., Rahmanian, R., Pilarz, M., & Stains, M. 2015, *CBE-Life Sci. Educ.*, 14, 1
Vygotsky, L. 1980, *Mind in Society* (Cambridge: Harvard University Press)
Vygotsky, L. 1986, *Thought and Language* (Cambridge: MIT Press)
Watkins, J., & Mazur, E. 2013, *J. Coll. Sci. Teach.*, 42, 36
Wood, W.B. 2009, *Annu. Rev. Cell Dev. Bi.*, 25, 93
Zingaro, D., & Porter, L. 2014, *Computers & Education*, 71, 87