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Instructional strategies and information technologies used for supporting the undergraduate mathematics teaching process: Scoping review protocol

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ABSTRACT

Evidence from previous studies shows that in undergraduate programs, the highest rates of academic failure are in mathematics courses, especially in engineering programs. To reduce the failure rate, professors use several instructional strategies and information technologies. In this paper, a scoping review protocol is presented, based on the framework proposed by Arksey and O'Malley (2005), to answer the following research questions: 1) What are the instructional strategies that have been most successfully used for teaching mathematics at the undergraduate level? and 2) Which information technologies have been used to implement these instructional strategies? The scoping review was performed through three electronic databases: SCOPUS, ERIC and JSTOR.

1. Introduction

There is evidence of the struggle that undergraduate students face regarding passing math courses. Studies from countries around the world show that a large percentage of students fail to pass mathematics courses in their last year of high school or first year of college (Darr & Wessel, 2018; Kafata & Mbetwa, 2016; Oliveira & Freitas, 2016; Saxe & Braddy, 2015). This is a problem that contradicts the increased interest in recent years of several countries for promoting STEM (Science, Technology, Engineering and Mathematics) disciplines as a way of improving workforce development and progress (FUMEC, 2016; OECD, 2015; Yaşar et al., 2006).

1.1. Instructional strategies based on information technologies

For the purpose of this study, an instructional strategy refers to techniques aimed to motivate and help students in keeping their attention focused, organize their information for understanding and remembering; and to enable teachers to monitor and assess their learning (Akdeniz, 2016). In other words, the various methods and activities educators and trainers use to help students or participants achieve the learning objectives Wolfe (2010). Following the previous definition, examples of an instructional strategy are: In

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Thevathayan and Hamilton (2017) use the strategy of project-based learning with their own developed intelligent tutoring system to improve student design skills and to promote the collaboration between teacher and students. Another example is presented in Alhazbi and Ismail (2010) that propose the use two instructional strategies: iterative learning and formative assessment, and their own developed video game to overcome students "fear" of programming and improve their satisfaction. In Lee, Pradhan, and Dalgarno (2008). use the strategy, interactive visualization and the software BlueJ[1] to investigate the effectiveness of the graphical features of BlueJ as a cognitive tool while performing coding tasks as part of a test; and the use of screencasts (video screen captures) of BlueJ to provide scaffolding during learning, which involves the provision of temporary support structures to assist learners in attaining the next stage or level in their development.

1.2. Instructional strategies for teaching mathematics at an undergraduate level

There are literature reviews that aim to identify instructional strategies for mathematics teaching, which can be classified as follows:

(i) *Systematic reviews of educational methodologies related to topics associated with college-level math*. Rakes, Valentine, McGatha, and Ronau (2010) present a systematic review of 82 studies to identify the methods of instructional improvement in Algebra. Five categories of improvement strategies emerged: technology curricula, non-technology curricula, instructional strategies, manipulatives, and technology tools. All five of these strategies yielded positive, statistically significant results. Furthermore, the learning focus of these strategies moderated their effects on student achievement.

(ii) *Reviews of didactic methods in the teaching of science at the University level*. Sullivan (2011) presents a general report on teaching mathematics to Australian students that highlights 6 key principles for effective teaching of mathematics: articulating goals, making connections, fostering engagement, differentiating challenges, structuring lessons and promoting fluency and transfer. Another example is presented in Shamsudin and Yusoff (2014). They present a systematic review on science education in Malaysia which leads to the importance of boosting creative teaching based on learning styles.

(iii) *Reviews of teaching methodologies applied in other educational levels*. For instance, Fahmy, Schroeder, and Chatti (2014) present a critical analysis of the research on Video-based learning (VBL) based on 76 studies. Four dimensions were identified: effectiveness, teaching methods, design and reflection. Most of the reviewed case studies asserted the efficacy and usefulness of VBL as a powerful medium used in education. Young et al. (2012) present a review of more than 300 articles on serious gaming for education in the K-12 level. Evidence on the effects of video games on language learning, history, and physical education (specifically exergames) was found, but little support for the academic value of video games in science and math was described. Heo and Choi (2014) describe an analysis of a mathematics flipped classroom experience in middle school in Japan. Self-directed learning of the students was found to have a positive relationship with academic achievement. Rocha and Araújo (2016) present a review on 30 studies on mobile learning for teaching mathematics and science in different educational levels. Most of them highlighted a positive impact of the application of m-learning activities.

However, the related studies mentioned above were focused on the search of previous works on a particular methodology or instructional strategy (e.g. video-based learning, video games, among others) in primary and secondary educational levels. The aim of our proposal is to review the diversity of instructional strategies and information technologies that can be applied to teaching mathematics at the undergraduate level.

1.3. Review objective

In this paper, we present a protocol of a scoping review that has the aim to provide a comprehensive and qualitative synthesis of the state of knowledge related to instructional strategies that have been used to support teaching mathematics at the undergraduate level.

2. Methods

2.1. Study design

A scoping review is an approach to reviewing the literature. The extent to which a scoping study seeks to provide in-depth coverage of available literature depends on the purpose of the review itself (Arksey & O'Malley, 2005). The methodology adopted to this scoping review was based on the framework proposed by Arksey and O'Malley (2005) to determine the value of undertaking a full systematic review. All phases of the scoping review are described in the following sections.

2.2. Research questions

This study focused on two research questions to establish what are the best combinations of an instructional strategy and

[1] https://bluej.org/.