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Potential of Flipped Learning Pedagogy in Mathematics Education: A Review Study

Introduction

Over time, some instructional strategies may become outdated and fail to meet learners' needs, and some extraordinary circumstances (e.g., COVID-19 pandemic) necessitate adopting innovative methods in education. Referring to this issue, Borba (2021) revealed that the pandemic changed the agenda of mathematics education, transforming students' homes into their classrooms. This situation reflects the concept of flipped learning pedagogy (FLP) which combines face-to-face and online learning and encourages students to take an active role in their own learning (Cevikbas & Kaiser, 2021). Mathematics educators (Bakker et al., 2021; Engelbrecht et al., 2020) reported various opportunities of hybrid learning modes, in particular FLP, to "redefine learning spaces, removing barriers between the home and school and making learning more accessible in a multiple of ways" (Attard & Holmes, 2020, p. 18). Although FLP can create numerous benefits for mathematics education, learners and instructors may encounter some important challenges when inverting mathematics instruction, for example, paradigm shift, creating new content, lack of competence and experience in the use of technology, and technological glitches (Cevikbas & Kaiser, 2020).

Overall, in the face of the expectations surrounding this innovative pedagogy, there is a lack of research on the opportunities and pitfalls of FLP in mathematics education. Therefore, the current review study aims to bridge this gap and explore the potential of flipping mathematics instruction based on empirically proven results from the literature. This review contributes to the field providing an insight into successful implementation of FLP in mathematics education. Based on the discussion described above, the following research question was addressed to explore evidence from the literature for the potential of FLP in mathematics education: What opportunities and pitfalls does FLP present for mathematics education?

Conceptualization of Flipped Learning Pedagogy

FLP is an innovative pedagogy that provides lectures outside of the classroom and performing active learning activities inside the classroom (Bergmann & Sams, 2012; Cevikbas & Kaiser, 2020). The initial attempts define FLP as schoolwork at home and homework at school (Lage et al., 2000), although recent approaches go beyond this definition (e.g., Bishop & Ver-

In: IDMI-Primar Goethe-Universität Frankfurt (Hrsg.),
Beiträge zum Mathematikunterricht 2022.
56. Jahrestagung der Gesellschaft für Didaktik der Mathematik. WTM.
https://doi.org/10.37626/GA9783959872089.0

leger, 2013; FLN, 2014). Bishop and Verleger (2013) identify two components of the FLP, interactive learning activities in groups in the classroom setting and computer-based individual learning activities out of the classroom. Bishop and Verleger's approach required to include lecture videos in pre-class activities of FLP. Although it is also possible to use other kind of materials such as reading texts, lecture notes, and podcasts, many learners find videos more engaging than textual aids (Bishop & Verleger, 2013). In another format, instructional or explanatory videos or other learning materials can be used in the classroom, rather than at home (Howitt & Pegrum, 2015), or videos may be optional instructional resources (Bergmann & Sams, 2012), which these approaches might be appropriate when not all learners are able to access videos at their home because of technical reasons. A well-known definition is developed by Flipped learning network (FLN, 2014), as follows:

> "Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter."

FLN identifies four core elements of FLP with using the acronym F-L-I-P: (flexible environment, learning culture, intentional content, and professional educator, for details see FLN, 2014). Moreover, Chen et al. (2014) added extra three letters, P-E-D (progressive activities, engaging experiences, and diversified platforms), to the F-L-I-P acronym for FLP to specify it for higher education. Furthermore, most recent studies modified the concept of FL based on the current situation after COVID-19 pandemic as it was not possible to conduct face-to-face instruction in most regions around the world. In this situation, researchers presented a fully online FL approach that combines asynchronous and synchronous online learning phases (Jia et al., 2021; Stöhr et al., 2020). All these approaches to conceptualizing FLP emphasize the active role of learners under the guidance of their instructors. In a nutshell, educators can benefit from the rich conceptual and theoretical perspectives of FLP, but it cannot be seen as a panacea for mathematics education.

Methodology

To explore the opportunities offered by FLP and its pitfalls, we searched the literature in June 2021 using databases of Web of Science, Scopus, ScienceDirect, and EBSCO-Teacher Reference Center by means of particular keywords: (flip* OR invert*) AND (class* OR learn* OR teach* OR instruction) AND (math*). We focused on peer-reviewed research articles published in English in the field of mathematics education. Our search yielded 4763 records and we included 97 studies in our review and analyzed them based on the qualitative content analysis. The analysis concentrates on 1) the opportunities of FLP and (2) the pitfalls of FLP.

Results and Discussion

We can summarize the main opportunities and pitfalls of FLP from the perspectives of learners and instructors, focusing on their academic, psychosocial, affective, cognitive, and pedagogical developments as follows:

The analysis indicates that the most commonly reported opportunities of FLP relate to its positive impact on students' achievement, learning progress, engagement, and collaborative/cooperative group work. In general, the most widely cited category concerning FL opportunities is individuals' *psychological and affective development* (e.g., motivation, satisfaction, self-efficacy, self-confidence, perception, enthusiasm, attitude, and interest), followed by *pedagogical development,* (e.g., time management, engagement, flexibility and equality in learning, and transparency); *academic development* (e.g., achievement, understanding, and time-on-task); *social development* (e.g., interaction, collaboration, discussion, dynamism, and communication); and *cognitive and meta-cognitive development* (e.g., self-regulation, metacognition, diagnosing misconceptions and learning difficulties, awareness, decision making, and reasoning). It is unexpected that only a relatively small number of studies are reporting opportunities to foster students' social development using FLP due to the high importance of collaborative learning and social interaction in FLP.
In addition to the numerus opportunities that FLP offers for both learners and instructors, several pitfalls emerge when flipping mathematics classrooms. In other words, almost half of the studies analyzed indicated that flipped mathematics classrooms were subject to several pitfalls that can be classified under the four main categories: (1) *pedagogical issues* (e.g., start-up effort, workload, time consuming activities, lack of preparation for class hours, adaptation problems, disengagement, difficulties in guiding students), (2) *affective issues* (e.g., stress, anxiety, frustration, being bored, and lack of motivation) (3) *cognitive issues* (e.g., difficulties in remembering the content of the pre-class tasks and low task orientation), and (4) *technical issues* (e.g., Internet connection problems and a lack of competence in the use of technological tools).

Overall, the distribution of the opportunities and pitfalls of FLP identified in our review indicated that the opportunities of FLP predominate. This is an encouraging result concerning the integration of FLP in mathematics education. Results of our literature survey indicate that the instructional approaches must be attractive to students, acceptable to teachers, and robust in use (Foster et al., 2022). In meeting these criteria, FLP can play a crucial role in improving mathematics education, although it is not a silver bullet to solve problems in mathematics education. In this vein, our review study contributes to the growing body of FL research and provides insight into the potential of FLP in mathematics education.

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