Digital game-based learning in primary school mathematics education

Omer Oktay

Brunel University

One part of my PhD research explored how Black and Wiliam's five key strategies for effective formative assessment can apply digital game-based learning (DGBL) in mathematics education through primary school teachers' views. 10 primary school teachers in England participated in interviews. Results of a thematic analysis indicated that teachers believe that different student characteristics and game types significantly influence the potential of DGBL as an effective formative assessment tool for mathematics education. Furthermore, teachers emphasized that the games that are widely used in mathematics education are far from fulfilling the five key strategies that Black and Wiliam's framework suggests.

Keywords: digital game-based learning, primary school mathematics education, formative assessment, teachers' views.

Introduction

Digital games have recently been considered promising tools for educational purposes (Byun & Joung, 2018). Particularly, the attractive elements and the authentic environments that they provide have been presumed to be effective in increasing students' motivation, engagement, enjoyment, and academic achievement in various domains (Clark et al., 2016; Girard et al., 2013; Ke, 2016) including mathematics (Eseryel et al., 2014; Ke & Clark, 2020; Kebritchi et al., 2010).

In mathematics education, digital game-based learning (DGBL) research has focused on both its direct effect on students' academic achievements (Chang et al., 2012; Hung et al., 2014; McLaren et al., 2017) and its influence on concepts related to learning such as motivation (Eseryel et al., 2014; Hung et al., 2014), engagement (Beserra et al., 2019; Eseryel et al., 2014; Moon & Ke, 2020), and enjoyment (Chang et al., 2012). Although some contradicting findings have been reported, these studies have mostly revealed positive outcomes in terms of DGBL's influence on both academic achievement and motivation, engagement, and enjoyment in mathematics lessons. Furthermore, the findings mostly indicated that these positive effects are either not mediated by factors such as different student characteristics (Ke & Clark, 2020; Nadolny & Halabi, 2016) or mediated in favour of low achievers (Chang et al., 2012; McLaren et al., 2017).

On the other hand, this large body of research has shown several limitations. First, the research has not been able to provide a comprehensive conclusion about DGBL's effectiveness due to the diversity of game types with different characteristics. Second, the potential of DGBL as a formative assessment tool has not been explored thoroughly. Third, teachers' observations and views on DGBL's efficacy in mathematics learning have been widely neglected. My research aimed to address these gaps by exploring primary school teachers' views on DGBL's effectiveness in mathematics education, specifically, as a formative assessment tool. Thus, I developed the following research questions:

1. How do primary school teachers in England utilise DGBL in mathematics education?
2. How can formative assessment frameworks apply to their DGBL approaches?
    a. Do primary school teachers' views on the effectiveness of digital games in mathematics education apply to Black and Wiliam's (2009) formative assessment framework?
    b. Do primary school teachers' views on the effectiveness of digital games in mathematics education apply to Burkhardt and Schoenfeld's (2018, 2019) Teaching for Robust Understanding (TRU) framework?

In this paper, I briefly share my findings on whether primary school teachers' views on the effectiveness of digital games in mathematics education apply to Black and Wiliam's (2009) formative assessment framework. The following sections overview the framework, the methodological design, my findings, and discussion.

Theoretical Framework

Concluding from Ramaprasad (1983), Wiliam and Thompson (2008) suggest three main processes in learning and teaching: identifying where the learners are in their learning, identifying where they are going, and identifying what steps need to be taken to get there. Distributing these three main processes over three main agents (teacher, peer, and learner) of a learning environment, Black and Wiliam (2009, p. 8) propose the five key strategies for effective formative assessment as follows:

1. Clarifying, understanding, and sharing learning intentions and criteria for success.
2. Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding.
3. Providing feedback that moves learners forward.
4. Activating students as instructional resources for one another; and
5. Activating students as the owners of their own learning.

<table>
<tr><th></th><th>Where is the learner going?</th><th>Where the learner is right now?</th><th>How to get there?</th></tr>
<tr><td>Teacher</td><td>Clarifying and sharing learning intentions and criteria for success (1)</td><td>Engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding (2)</td><td>Providing feedback that moves learners forward (3)</td></tr>
<tr><td>Peer</td><td>Understanding, and sharing learning intentions and criteria for success (1)</td><td colspan="2">Activating students as instructional resources for one another (4)</td></tr>
<tr><td>Learner</td><td>Understanding, and sharing learning intentions and criteria for success (1)</td><td colspan="2">Activating students as the owners of their own learning (5)</td></tr>
</table>

Figure 1: Aspects of formative assessment (Black & Wiliam, 2009, p. 8)

Methodology

As a part of a quasi-mixed-methods design, I investigated whether primary school teachers find DGBL suitable for Black and Wiliam's five key formative assessment strategies in mathematics education through qualitative interviews. Ten primary school teachers in England participated in the interviews. Following Braun and Clarke's (2022) guidance, I conducted a thematic analysis. The following section overviews my findings on Black and Wiliam's (2009) formative assessment framework.

Findings

Theme 1: The traditional way

In terms of DGBL's suitability for clarifying and sharing learning intentions and criteria for success, teachers were not univocal as some of them did not find digital games useful for this purpose whilst others were positive about it. The former group indicated that even when they use digital games, they mainly prefer sharing the learning intentions and criteria for success verbally instead of using any feature that games offer. Moreover, some teachers argued that for this strategy, the traditional way of interaction is more effective than digital games. The teachers underlined the importance of constantly reminding the learning objective to the students and indicated that, on that account, following a traditional path would be more effective as the games do not regularly remind students of the learning objectives.

Although the latter group were more optimistic about digital games' potential in this matter, some teachers' explanations revealed that how they utilise digital games to clarify and share the learning intentions and criteria for success does not apply to Black and Wiliam's (2009) point of view. Instead of using the game to share the learning objectives, teachers mainly use it to attract students' attention while sharing the objectives verbally. Finally, some teachers indicated that although they are open to making use of digital games for this purpose, it would depend on whether the game allows it or not.

Theme 2: Collaborative features and their risks

This theme addressed both the second and fourth key strategies of Black and Wiliam (2009) for an effective formative assessment. Regarding "engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding" (p. 8), teachers mainly mentioned the collaborative features of digital games. Some teachers pointed out that collaboration within gameplay sessions can allow students to engage in effective discussions about the subject as they will need to help each other. In addition, teachers indicated that team competitions can further increase this potential as they not only help each other voluntarily, but they also need to help each other to win against the other groups.

It should be noted that these teachers exemplified their arguments with Times Tables Rock Stars since other teachers had a different perspective on this game. For other teachers, while being suitable for competition, Times Tables Rock Stars is not suitable for collaboration and, thus, does not provide an environment where effective classroom discussions can be developed. Finally, teachers underlined that collaborative play also carries the potential for distraction as students can easily go off topic or disturb their peers who are working independently by making noise when collaborating with their teammates. Teachers suggested that this could disadvantage students who like to work independently.

In terms of "activating students as instructional resources for one another" (p. 8), teachers' insights were mainly positive, however, they approached it from different perspectives. For example, whilst some teachers indicated that they encourage students to work within groups to help each other through the activity, other teachers suggested that it could be quite beneficial if students help each other with questions or items that they have struggled with once they receive their results. Moreover, teachers pointed out that it would be beneficial if a digital game had a multiplayer mode although the games that they use do not have a such feature. However, neither teacher mentioned any key

element of collective learning such as "motivation", "social cohesion", "personalisation", and "cognitive elaboration" (Wiliam, 2018, p. 156). On the other hand, some teachers' warnings about the risk of distraction when using digital games to engineer effective classroom discussions may also be relevant in this matter as teachers pointed out that environments like this could be highly distracting and counter-effective for some students.

Theme 3: Potential barriers

Another important theme developed in terms of the second strategy of Black and Wiliam (2009) for an effective formative assessment was related to the obstacles to using digital games for that purpose. Teachers mainly argued that to be able to provide an environment where students can participate in effective discussions about the topic and teachers can elicit evidence about their understanding to take necessary measures if there is any misconception, games will need some advanced features. For example, some teachers underlined the importance of an overall teacher account to conduct such strategies whilst others mentioned that even though many games have these features, they are only available on premium accounts which require budgets. Teachers maintained that the games that they use are not quite eligible for this purpose as they are mainly for practising and increasing fluency. Although they acknowledged that, potentially, there are games which are suitable for this purpose with their advanced features how they use DGBL is based on utilising them as practice-based extensions of real tasks instead of well-planned game-based lessons. Finally, some teachers emphasised the importance of different student characteristics and suggested that, especially, for students who are usually too shy to participate in classroom discussions, digital games cannot serve as an alternative.

Theme 4: Basic level feedback

Considering "providing feedback that moves learners forward" (p. 8), teachers indicated that the games that they use mainly provide basic-level feedback (knowledge of response or knowledge of correct response) instead of elaborative feedback about students' progress. They underlined that as this type of feedback does not provide insight into students' processes, its influence remains short. Furthermore, some teachers argued that paper-pencil-based feedback would be more effective than the feedback generated by digital games as it can show the process that students followed to come up with their answers whilst the feedback that digital games provide is mainly based on whether their answers are correct or not and misses useful information about students' thinking. In terms of their contribution to generating feedback, teachers mentioned that they mainly follow methods such as walking around the classroom and monitoring students' progress, and interacting with them when they detect misconceptions or learning issues. Some teachers argued that this method generates the most effective feedback within DGBL, and they suggested that if the digital game is played on the interactive board as a class, generating feedback by monitoring what students are doing can become easier.

Theme 5: Self-learning

Regarding digital games' potential for "activating students as the owners of their own learning" (p. 8), teachers were mainly divided into two groups. The first group argued that a teacher's presence is still necessary as students' progress will need to be carefully

monitored. They indicated that without a teacher who controls students' activities during DGBL, students may interact with the game in ways that are not academically beneficial. Finally, they suggested that as most games are practice-based, the learning part happens before the gameplay, thus, a digital game cannot be effective in learning without a teacher. Teachers who find digital games potentially effective in self-learning underlined the importance of student characteristics. They pointed out that students who usually have difficulty with learning mathematics may struggle with learning with a digital game on their own. They emphasised that games could fail to point out misconceptions, therefore, they should be used with caution. They suggested that if digital games are going to be used for this purpose, it should be based on small steps.

Discussion

My findings demonstrated that although the literature reveals highly positive outcomes regarding DGBL's potential in mathematics education, primary school teachers in England are not completely in the same line with the literature. In terms of Black and Wiliam's (2009) five key strategies, the findings indicated that it is difficult to conclude that DGBL satisfies the requirements of an effective formative assessment. It appeared that particularly two factors have a significant influence on DGBL's potential in this regard.

First, the characteristics and capacities of the mainstream digital educational games used in mathematics education strongly affect their ability to serve as effective formative assessment tools. The most popular digital educational games that teachers use in mathematics lessons are simple and practice-based games that target increasing students' procedural fluency in specific topics such as times tables instead of addressing higher-order skills such as strategic competence or adaptive reasoning and fall short in providing effective feedback. Thus, the learning environments that they provide do not address the requirements of an effective formative assessment framed by the authors. Teachers acknowledged that more advanced games could provide such environments.

Second, different student characteristics have a strong effect on DGBL's potential to address the authors' five key strategies. As opposed to the literature, teachers suggested that the DGBL environments are not completely inclusive for all kinds of students and indicated that lower achiever students are more disadvantaged than higher achiever students in those environments. Furthermore, most teachers pointed out an imbalance between boys and girls in terms of the effectiveness of DGBL in mathematics education. Teachers, therefore, argued that DGBL does not yet carry the potential of providing a maths learning environment where effective classroom discussions are engineered, misconceptions are detected, and productive feedback is generated as the authors suggest.

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