Towards a Hybrid Learning Space for Engaging Primary Pupils in Physically-Active Mathematics: the case of Numberfit

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Abstract. In this paper, we present a case study of an intervention in which physical and tangible resources and activities for mathematics are enhanced through digital elements. This approach is a product of an educational social enterprise Numberfit. An online platform allows the teachers and Numberfit facilitators to design a lesson plan for physically active mathematics where students interact with, collaborate within groups and compete with other groups while practising a range of topics and get points for their behaviour and solutions. These points are recorded through an app that feeds data on a leaderboard which is displayed on the screen. Some lessons are planned as a webcam competition that is led by a remote Numberfit facilitator while displaying what is going on and leaderboard from several schools. Following smaller trials, Numberfit is now being scaled up and piloted at three different schools. This paper describes the engaging hybrid learning space that is created through the Numberfit approach, as well as preliminary findings of the empirical research that explores whether and how students' motivation and attainment are affected.

Keywords: physically active mathematics, self-efficacy, affect and motivation.

1 Introduction

Hybrid learning spaces offer the possibility of engaging students in a rich variety of activities, combining elements of two worlds: face-to-face support and contact with peers, and the opportunities afforded by digital technology [1,2]. In particular, hybrid spaces at primary school classroom offer opportunities for encouraging interactivity, deeper student engagement and emphasis on student-centered learning [2,3]

In this paper, we describe an ongoing pilot of a physically-active intervention for mathematics and its associated resources and pedagogy. This intervention combines physical and digital elements. The goal of Numberfit social enterprise is to improve engagement and attainment in Mathematics and reduce children sedentarism through different types of physically active maths activities where students interact with their

peers while practicing Mathematics over a large range of curriculum linked topics (e.g. arithmetic, fractions, etc.).

This digital technology helps teachers to deliver maths session, while it allows children to interact with learners in other schools. What we present here is an online platform that provides resources for the physical lesson to prepare the session, and registers what is happening in the classroom during the session.

Numberfit's approach is motivated by practical teaching experience and relevant research around students' attitudes towards mathematics, a topic that often provokes worry, stress and even feelings of powerlessness [4]. These feelings are often collectively referred to as maths anxiety [5] and have been associated with poor performance in both primary [6-7] and secondary students [8]. In particular, previous research has found that early primary children's maths anxiety was negatively related to their use of more advanced problem-solving strategies, which in turn resulted in poor maths achievement [6]. Children's motivation towards learning is strongly related to a construct known as self-efficacy i.e. their self-belief and judgment of (rather than actual) capabilities to execute courses of action required to achieve the desired performance [9]. Within the education domain, self-efficacy has been referred to as academic self-efficacy, which is students' belief in their capacity to learn and perform specific academic tasks [10]. Encouragingly, the classroom environment has been shown to positively impact maths performance through its mediating effect on self-efficacy [11]. Similar current research has shed light on the importance of promoting physical activity within the school curriculum not only for physiological benefits, but also psychological improvements [12]. Recently, studies have demonstrated significant interaction between physical activity, cognitive functions and academic attainment [13].

Based on the above, we are exploring how learners interact in the hybrid space that is created by the Numberfit intervention, presented in more detail in Section 2 below. On Section 3 we describe our methodology for the empirical research that looks into the impact of this approach and on Section 4 we provide some preliminary results and share our future work plans.

2 The technology-enhanced NUMBERFIT sessions

Numberfit sessions combine physical activity with maths questions to improve children's wellbeing and raise engagement through gamified and personalized active mathematics sessions thereby minimizing sedentary learning time. These sessions have been enhanced with technology, creating a hybrid learning space in which a big part of the activities happen in the physical space, while some of them are recorded and are included in the digital space. Some of the hybrid aspects are described in Table 1 below.

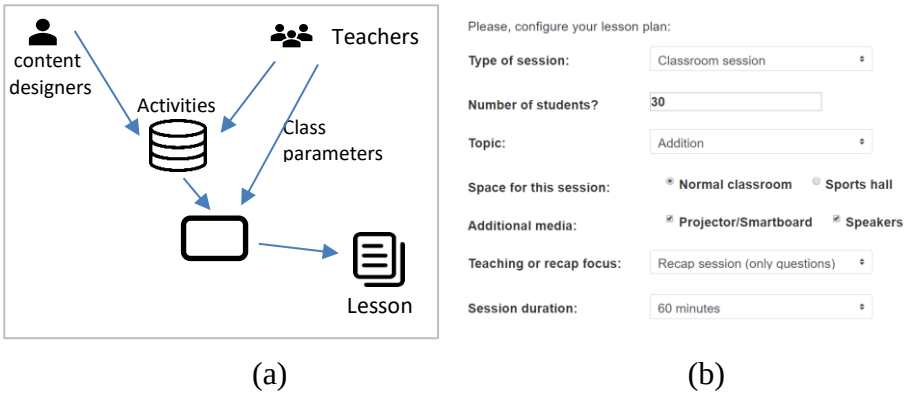
Table 1 Hybrid space dimensions of the Numberfit intervention

Hybrid Space dimension		
Resources	Digital *Children watch video of an action and repeat it.*	Physical *Children interact with physical question cards*
Peer interaction	Face to face *Children interact with peers in their classroom*	Remote *Classes interact using the webcam*
Interleaving time	Synchronous *Competition in real time, synchronized through webcam*	Asynchronous *Competition across several sessions. Sessions without webcam*

2.1 Database of activities and user interface for teachers

A range of activities are stored in a database, and classified by physical activity level, resources needed, space needed, number of adults needed, etc. These parameters allow the session to be adapted to the specific class of students and circumstances (see Fig. 1). When planning the session, the teacher can specify the number of students, the topic and some aspects related to the hybrid space (see Fig. 2).

The activities are designed to either teach mathematical concepts, or to practice topics which the teacher has already covered in class, or to be used as games e.g. tossing a bean bag to score points after answering a mathematical question. They are videos explaining each of the activities, as well as some additional digital resources to be displayed over the smartboard. After or during the session, the teacher can write feedback about each of the session plans, which are stored on the platform.



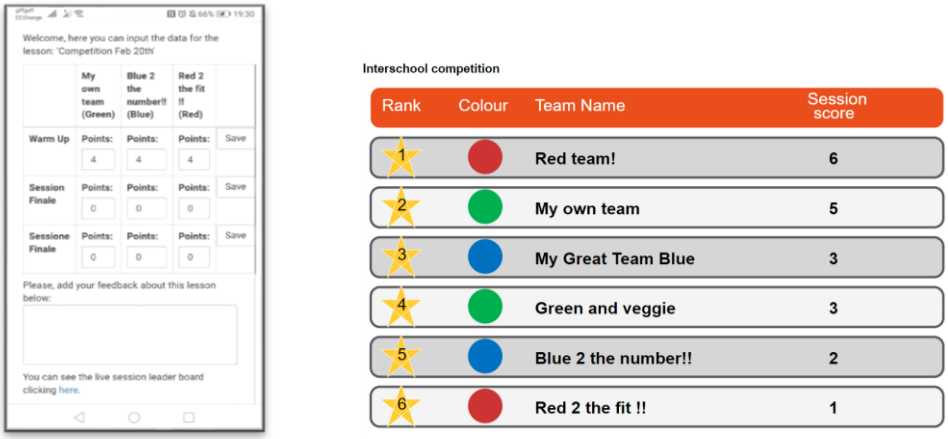
(a) (b)

Fig. 1. (a) Online system structure **(b)** Configuration of session parameters

2.2 Recording evidence, scoring the activities and leaderboard

Many of the activities proposed in the platform are games which are played in teams, encouraging collaboration and competition. The games are scored during the session with the help of a patented plastic mat with 'pockets' for the answers. This dramatically reduces marking time because the back of the answers complete an image that when flipped the teacher can quickly recognise visually (this Visual Answer System is pending patent; for details see https://www.numberfit.com).

Other digital technology is used to record the scores of each team on the platform during the session. This can be done either in the web interface to the teacher portal or in an app. The recorded scores are displayed on a leaderboard and shown to the students during the session.



(a) (b)

Fig. 2. (a) Mobile device interface to input points and (b) Interactive Whiteboard Leaderboard.

2.3 Webcam competition

The Numberfit approach includes two types of sessions. The first is a 'classroom Numberfit session' and contains all the elements described above. The second type is a "webcam competition" session, in which teams of pupils from several schools can compete over a webcam. First, the teacher logs into the teacher portal where the session plans can be read. Then, the teacher portal provides a link to access the interschool competition, which should be accessed at a specified time. The session is supported by an online facilitator (a Numberfit employee) who provides instructions, keeps timing, motivates the teams and monitors the online display, e.g. showing the required information when the teams are playing the games. After the pupils finish a game, the teacher inputs their scores, which are directly displayed on a leaderboard.

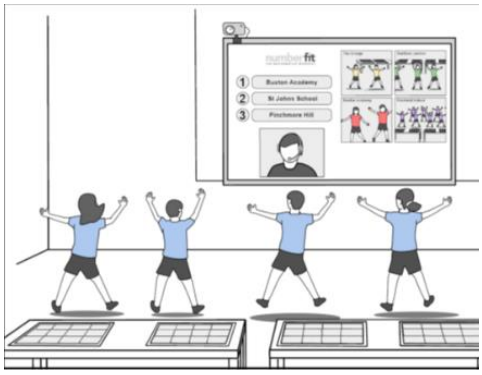


Fig. 3. Webcam competition diagram. Image Copyrighted

3 Methodology

At the time of this writing, a research program is taking place in two schools located in London, with 119 students of Year 3 and Year 4 (8 to 10-year-olds). This part of a bigger Numberfit pilot across several schools for a term. Each session lasts one hour per week and there is a different lesson plan every week. Each week students are competing in their own school with their classmates whereas every other week students are competing with same year students of another school through a webcam.

It is challenging to conduct research in this area. Going beyond coarse-grained data from performance tests or self-reports, we recognize the need to triangulate any findings with context-aware, human-labeled systematic observational data. As such, we are an approach based on the BROMP protocol for quantitative field observations of student affect and behavior [14], and a digital observation tool called "Observata" that allows for open and axial coding (with pre-defined codesets) [15]. Observata initiates a lesson observation protocol based on a learning scenario, including in lesson annotation of pre-defined tools, artefacts, actors, learning goals and related activities. The affective and behavioral states of each student and how this evolves over the sessions with and without the webcam (webcam=interschool competition) are being observed. The focus is primarily in the following codes: affective states (boredom, confusion, frustration, delight, and engaged concentration/flow) as well as behavioral states/engagement (off task, on task, misbehavior).

In addition, for the reasons discussed in the introduction, we use an adapted version (21 items) of the Self-Efficacy Questionnaire [16] before and after a period of 10 weeks of the intervention and the Mathematics Fluency (MF) sub-test of the Woodcock–Johnson III Tests of Achievement, [17] that requires participants to answer as many single-digit addition, subtraction, and multiplication problems as possible within a 3-min period. The test was administered before and after sessions in the beginning and the end of the intervention period in two equivalent versions.

4 Preliminary results and discussion

Because detailed data analysis is underway and due to space limitations, we only share some of the highlights of our research so far. Our empirical observations are indicating that, as expected, children tend to be more actively engaged in a Numberfit session than in their typical classroom. In addition, in some classes, students appear more collaborative and are displaying fewer moments of negative behavior (off-task and misbehaviour) when there is competition with children from another school rather than when competing with their classmates.

From quantitative data, we have only analyzed the Y3 MF results that show a statistical significant difference between the number of attempts and the accuracy of the answers in the MF test from when students started the Numberfit intervention and two weeks down the line. This may be indicative of the fact that while students are participating in the intervention their confidence to attempt questions and their accuracy is increasing. The SEQ data analysis is pending final post-intervention period tests.

Of course, the picture is more nuanced than what the quantitative data through the instruments above can provide, and we see specific benefits that for now we cannot quantify but lead to further questions. For example, we are observing a qualitative difference particularly in low achieving pupils (as the Numberfit competition is specifically designed to be among equals across schools). This may be because they become more engaged as they are able to win competitions.

Our interest is now shifting to the role of the teacher in this setting and their professional development needs. We are keen to understand how the proposed structured of the Numberfit lesson and the digital resources are helping teachers or not adopt a varied pedagogical style. We are planning to analyse the feedback from teachers next.

In conclusion, the hybrid space experience that Numberfit offers blends the physical and the digital allowing scaling up the specific intervention. In further research, it would be interesting to explore how to give further recommendations to the teachers through the online system, depending on the specific constraints in the class (technology available, space required and adults in the class); allow more interactivity between the physical and the digital spaces and between the children of different classes; implement more ways to score the activities; use wearables to keep track of the students' physical exercise; and finally improve the learning analytics which are displayed to the teacher.

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