A Hybrid Learning Space for Physically-Active Mathematics: the case of Numberfit

Estibaliz Fraca [1], Maria Kambouri [2], Nicole Yuen [2], Rozina Bakirtzoglou [1], Gavin Mair [3], Ashley Highmore [3], Carys Hubbard [3], and Manolis Mavrikis[1]

[1] UCL Knowledge Lab. Institute of Education. University College London
[2] Institute of Education. University College London
[3] Numberfit Ltd., UK

Abstract. This paper presents the case study of an intervention called Numberfit that aims at capturing primarily students' interest in mathematics by combining team games and physical activity. We describe the hybrid learning space that is created through this approach that includes an online platform that allows the teachers and facilitators to design a lesson plan, input student scores and visualise a leaderboard. At the same time, various digital and tangible resources engage students in group (collaborative or competitive) activities while practising a range of topics in mathematics. We examine the changing role of the teacher and provide some methodological insights for conducting research in relation to student's affect, motivation and behaviour in this context.
Keywords: physically-active mathematics, hybrid learning spaces.

1 Introduction

Hybrid learning spaces (HLS) 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 [19,17]. In particular, hybrid spaces in primary school classrooms offer opportunities for encouraging interactivity, deeper student engagement and emphasis on student-centered learning [17,11].

In this paper, we describe an on-going design-based research project that aims to develop technology to support a physically-active intervention for mathematics and its' associated resources and pedagogy. Physically active learning (PAL) integrates whole body movement into the existing curriculum in subject areas other than physical education [15]. Numberfit combines physical and digital elements in different types of physically-active maths games where students interact with their peers while practising mathematics over a large range of curriculum linked topics e.g., arithmetic, fractions, etc. In an attempt to scale up the delivery of the intervention, Numberfit developed a platform designed to provide teachers with resources for the physical lessons to prepare and deliver the lesson, whilst allowing children to interact with learners in other schools as well as register what is happening in the classroom during the session.

Numberfit's approach is motivated by practical experience and relevant research around students' attitudes towards mathematics, a topic that often provokes worry, stress and even feelings of powerlessness [12]. These feelings are often collectively referred to as maths anxiety [12] and have been associated with poor performance in both primary [16,14] and secondary students [9]. Encouragingly, research has shed light on the importance of promoting physical activity within the school curriculum not only for physiological benefits, but also psychological improvements [5]. Recently, studies have demonstrated significant interaction between physical activity, cognitive functions and academic attainment [18]. While previous research indicates that teaching mathematics through physical activity (PA) is an effective method compared to traditional methods [10], there is little research focusing on teacher-led *in situ* interventions that have evaluated their impact within the mathematics domain [4,1]. In particular, to the best of our knowledge, there is little research going beyond purely academic performance and looking into motivation and student engagement in this context [3].

Based on the above, we are interested in how learners and teachers engage in the hybrid space that is created by the Numberfit intervention, presented in more detail in Section 2 below. In Section 3, we describe the methodology of our empirical research and the feasibility of doing research in this space. On the one hand, we aim to advance our understanding of the behavioural and affective states of primary students during physically-active learning. On the other hand, it is important to investigate the changing role of the teacher in this context, the challenges they face and any professional training needs in order to derive recommendations for classroom implementation of similar interventions. As such, in Section 4 we provide some preliminary results and discussion. We conclude the paper by reflecting on some of the challenges in this context and share our future work plans.

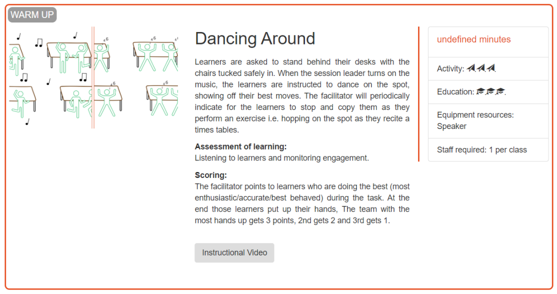
2 Digital technology in Numberfit sessions

We present below the current iteration of the platform that supports the intervention that has evolved over time following feedback from teachers. We start with an example to illustrate key features of this intervention.

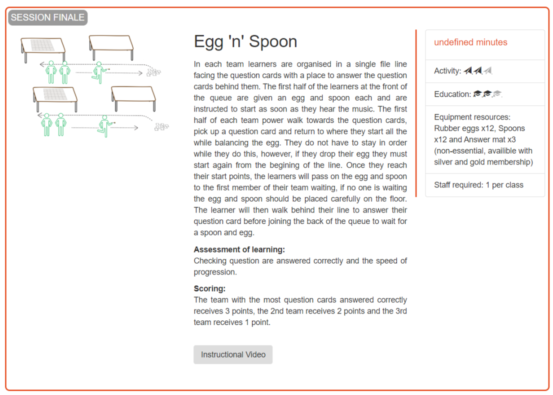
2.1 Example of a Numberfit session

In a standard session, the children are divided into three teams, and they are practicing a particular topic. For our example, let us focus on "Addition".

The session consists of two activities. The first of them (Figure 1(a)) is a warm up activity, in which the children are interacting with their team mates, following challenges that the teacher sets. In the second one (Figure 4(b)), they play a game, in which they need to solve as many questions as possible, which can be found in Question Cards (a physical resource the children interact with).



(a)



(b)

Fig. 1. Numberfit session games. Copyrighted.

Numberfit sessions combine physical activity with maths questions to raise engagement through gamified and personalized active mathematics sessions at the same time minimising sedentary learning time.

Most of the activities proposed in the platform are games which are played in teams, encouraging collaboration and competition. Hence, the teacher divides the students into three teams, which remain the same teams for all the intervention. The resources proposed by the platform have been designed following the British National Curriculum.

2.2 Hybrid learning space dimensions

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.

Table 1. Hybrid space dimensions of the Numberfit intervention

Hybrid Space dimension		
Resources	Physical *Children interact with physical question cards*	Digital *Teacher inputs scoring on the interactive leaderboard*
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 and connected classrooms*	Asynchronous *Competition across several league sessions. Sessions without webcam*
Physical activity	Children moving *Children running on the spot*	Children Not moving *Just standing listening to the teacher*

2.3 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 Figure 2). When planning the session, the teacher can specify the number of students, the topic and some aspects related to the hybrid space (see Table 1).

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.

2.4 Recording evidence, scoring the activities and leaderboard

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 *patent pending*; 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, displayed over the teacher smartboard, or in an app (shown in Figure 3(a)). The recorded scores are displayed on a leaderboard and shown to the students during the session.

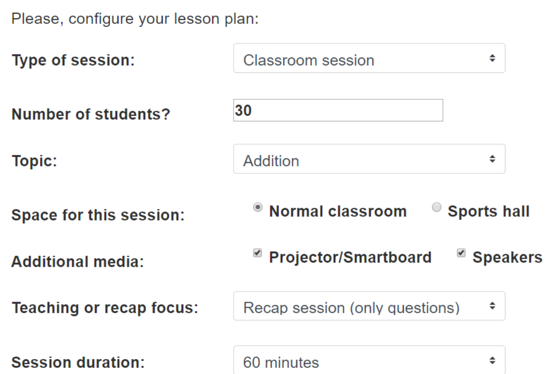
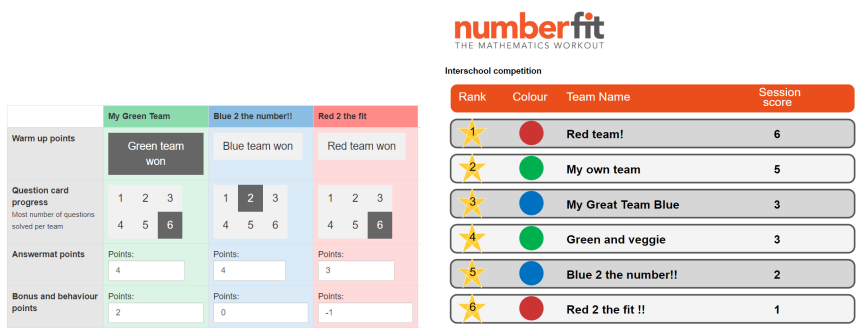


Fig. 2. Configuration of session parameters

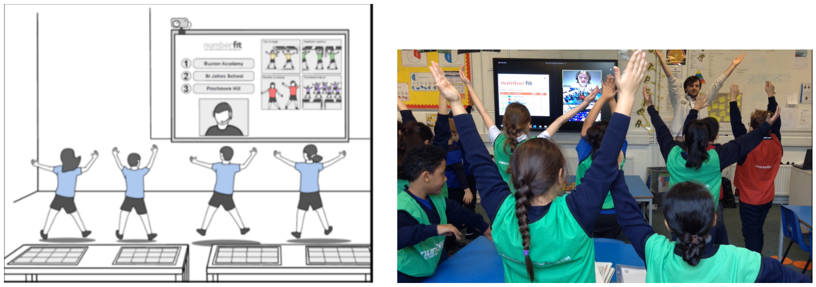


(a) (b)

Fig. 3. (a) Interface to input scores. This can be done by the teacher either on a tablet or on the interactive smartboard.(b) Interactive Whiteboard Leaderboard

2.5 Webcam competition

The Numberfit approach includes two types of sessions. The first is a 'classroom Numberfit session' and contains all the elements described above (Figure 4(a)). 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.



(a) (b)

Fig. 4. Webcam competition. Image Copyrighted.

3 Researching physically-active classrooms

A pilot research program took place in two schools located in London, with 119 students of Year 3 and Year 4 (8 to 10-year-olds). One Numberfit session took place each week, in which students were competing in their own school with their classmates whereas every other week students were 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 recognise the need to triangulate any findings with contextual human-labeled systematic observational data. As such, we are employing an approach based on the BROMP protocol for quantitative field observations of student affect and behaviour [2], and a digital observation tool called "Observata" that allows for open and axial coding (with pre-defined codesets) [7]. 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 behavioural states of each student and how this evolves over the sessions with and without the webcam are being observed. The focus is primarily in the following codes: affective states i.e. boredom, confusion, frustration, delight, and engaged concentration (flow) as well as behavioural states (off task, on task, and misbehaviour). The BROMP protocol recommends 20-second time sampling intervals of both student engagement and affect with the premise that these constructs are somewhat orthogonal (see [2]). A pilot indicated that due to various logistics and other pragmatic reasons, it is more realistic to focus the observation in the middle part of each classroom session of about 15 minutes.

Moreover, we draw data from four teachers who were observed during the sessions, as well as during their preparation and debriefing using the platform and the various digital and physical resources. This way, we analyse the intervention from two perspectives: The first one, from the perspective of how the intervention is received by students. The second one, from the perspective of the teachers and how they embrace technology and hybrid pedagogies.

4 Discussion

4.1 The student perspective.

We share some preliminary results and the hypothesis we are developing for further research. Our empirical observations are indicating that students generally engage positively in terms of both behaviour and affect, as expected perhaps due to the novelty of the intervention for the students. Teachers report increased confidence especially for low achieving pupils (as the Numberfit competition is specifically designed to be among equals across schools). This is aligned with related research in the field. In particular, the classroom environment has been shown to positively impact maths performance through its mediating effect on self-efficacy [8] i.e. students' belief in their capacity to learn and perform specific academic tasks [6]. Therefore, it is possible to hypothesise that a more engaging classroom environment may have an influence in long term academic performance through building self-efficacy from motivating and engaging mathematics experience. Further research will attempt to establish ways to quantify this effect, though we recognise that measuring, for example, self-efficacy for this target age and context is challenging.

Using the BROMP methodology, it is possible to record and quantify different aspects of students' interactions. For example, in some classes, students appear more collaborative and are displaying fewer moments of negative behaviour (off-task and misbehaviour) when there is competition with children from another school rather than when competing with their classmates. Anecdotally, this seems to be repeated in other classes and further research should check if the findings replicate across classrooms and schools.

4.2 The teacher perspective

Our interest is exploring the role of the teacher in this context and how they appropriate the technology to prepare and facilitate the Numberfit sessions.

It is clear that the preparation of a lesson is an important aspect of this process and of course a necessary step in establishing innovative pedagogy. Without this step, in pilot studies, we have observed the lessons working when the Numberfit facilitators are there but the teacher quickly losing control when the facilitators step back. As such, it became apparent that providing a systematic way to organise the class into the proposed Numberfit configurations was key. Technology, therefore, acts as a scaffold to guide the teacher through this preparation session. While we do not have a large sample of teachers to draw inferences, it seems that that the more experienced teachers appreciate this potential role of the platform and jump into using it, while the newcomers are apprehensive initially, have to be convinced of its value but once supported by the platform's structuring of the lesson can more easily adopt the approach. There are, therefore, important implications of the use of the platform as Continuous Professional Development, which we will consider in future work.

Reflecting on the observations and interviews of the 4 teachers across different classrooms and schools, we can extract some key reflections which can be transferable to how teachers can embrace other hybrid learning spaces.

The trade-off between flexibility and off-the-shelf lesson plan. As discussed, the Numberfit platform allows teaches to configure the lesson plan according to various parameters. This was a result of earlier design requirements that showed the need for flexibility that some teachers expressed. However, due to their high workload, and the need to have a way to embrace this approach without a huge time investment, we found out early in the process that this flexibilty was actually a barrier to adoption. We had, therefore, to find an adequate trade-off between allowing the teacher the possibility to configure the lesson plan, and giving a default lesson plan ready to be used. As such, the current platform encourages configuring a lesson according to some minimum parameters but beyond that it allows teachers to either mix and match activities or follow a default recommended activity. The aspects that teachers found particularly helpful is that they can pick a topic that they are working on anyway, and the sessions are themed to the corresponding mathematical concept and connected to physically-active learning. This would be difficult to do otherwise.

The challenges of preparation and lesson planning. Something which also took some time for teachers to fully appreciate was the time it takes to get used to the project 'technology'. With that we mean both digital components as the set up for communicating between classrooms, and the non-digital which includes assessment (answer-mats) and games between math exercises (gadgets such as mini beanbags, hula hops, eggs and spoons, etc). Even for the two digitally savvy teachers setting up the webcam, speakers and smartboard, and accessing the videoconference tool in their school's computers and network was rather challenging each time not least because of the number of things that could go wrong every time that these pieces of technology were setup. As we are beginning to identify these issues, the teacher on-boarding process through the platform makes these steps more visible and facilites the setup process.

Digitising physically-active learning and team activities. Teachers also reflected on the benefits of having a digital trace of an otherwise difficult setting to track. Starting from the quick setup of each team in the system, they found the group functionality useful, even if sometimes it can be quite rigid. This relates to the point above about configurability and something we can work in the future to improve. Equally important, they found necessary the ability to collect even coarse data from the team work that can be logged. This helps subsequent reporting for the individual students. This need is rooted in current realities, at least in education in England, where the standard of education is interlocked with performance measures (usually test scores). This shapes teachers' professional identities [13] where assessment has an important role less as a formative means to support teaching and learning, but more as reporting for both student and teacher quality. While technology should not be viewed as a fix to deeply rooted problems, we recognise that the reporting nature of these data appeals to some teachers. In future work, we would like to provide more accurate, granular and student-specific rather than whole-team data that can help on individualised support beyond serving a purpose for the leader-board.

More generally, teachers reported on their perceived and noticeable improvement of the lower groups, the "hard to motivate kids" who were won over by this. While we do not have the data to demonstrate this across schools, anecdotally, the teachers saw this a strong indicator of the potential success of such an intervention and the need for such a hybrid learning space to be created with lower achievers in mind. Of course the teachers recognised the effect of novelty, but they were encouraged that the rearranging of the space seems with its new dynamics seems to provide a boost in the right direction.

5 Conclusions

This paper describes a technology-enhanced physically-active approach to mathematics learning. We provide preliminary insights about conducting research in this setting and about the role, challenges and opportunities for teachers.

The hybrid learning space experience that Numberfit offers blends the physical and the digital allowing scaling up the physically-active classroom. Given prior literature and our preliminary results, the area warrants further research.

Methodologically, the use of the BROMP observation protocol through the Observata app allows us to get a glimpse into the behavioural and affective states of the students and answer research questions compare the different types of sessions. However, human labelled observations in classroom are very time consuming, resource intensive and with inherent limitations (c.f. Wragg,2013). The emerging field of multimodal learning analytics can provide solutions to this. Future work can concentrate on analysing such a classroom context through wearables that can keep track of the students' physical activity and new means of recording and analysing affective states.

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