Teachers' Perspectives on the Adoption of an Adaptive Learning System based on Multimodal Affect Recognition for Students with Learning Disabilities and Autism

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Abstract. Adoption of e-learning for those with special needs lags that for mainstream learners. Not much is known about barriers and facilitators that drive this disparity. The present study used focus groups and interviews to collect the views of 21 teachers taking part in preliminary evaluations of an adaptive learning system based on multimodal affect recognition for students with learning disabilities and autism. The system uses multimodal detection of affective state and scoring of performance to drive its adaptive selection of learning material. Five themes captured the teachers' views of the system's potential impact, especially regarding learning and engagement but also on factors that might influence adoption. These were: the potential of the system to transform their teaching practice; the ability of the system to impact on learning outcomes; the potential impact on teacher-student/peer to peer relationships; usability issues; and organisational challenges**.** Despite being highly motivated as volunteer testers, teachers highlighted barriers to adoption, which will need addressing. This finding underscores the importance of involving teachers and students in the design and development process.

Keywords: Adaptive Learning Systems, Mulitmodal Affect Recognition, Barriers to Adoption.

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1 Introduction

2020's COVID-19 restrictions led to a surge in uptake of language apps, virtual tutoring, video conferencing tools and online learning software, as educational establishments struggled to meet the needs of their students remotely [1]. Pre-pandemic, the adoption of computer-based learning for those with special educational needs lagged that for mainstream users [2]. This is in spite of obvious advantages.

E-learning is seen as an antidote to the challenges experienced by these learners in accessing the educational opportunities and support they need but are often denied. Types of intervention vary, from the device-based such as games or other software on laptops or mobile devices, to web based virtual learning environments. Depending on configuration they confer the advantages of a variety of multimedia content, and flexible scheduling both in time and location [3], all of which would seem to allow individualised instruction to meet the specific needs of the most cognitively challenged learners. Learners can progress through content at their own pace, spending as long as is needed on concepts that have not been fully grasped but skipping over those that have [4].

These interventions are generally well received by both special needs teachers and their students, being seen as fun and with the potential to improve student motivation [5]. However, in education widely, in spite of teacher training programmes, an increase in ICT resources, and the requirements of national curricula, there has been disappointingly slow uptake of ICT in schools by the majority of teachers [6].

Goodyear et al. [7] define online teaching and learning in general as "teaching and learning that takes place over a computer network of some kind" which includes "both synchronous and asynchronous forms of interaction as well as interaction through text, video, audio, and in shared virtual worlds". Such methods recently have been augmented with affect recognition to optimise the presentation of learning material. Recent reviews [8, 9] have highlighted an explosion of work on the use of artificial intelligence tools for education (AIEd) that detect affective states relevant to learning. These affect-detecting interventions operate via various sensors and machine learning models, and promote learning in corresponding ways: they can apply real-time data on student engagement to trigger an on-screen agent (e.g. [10]), or a human teacher to implement "just-in time" personalised interventions [11], or to drive the machine-assisted selection and presentation of learning material so that it adapts to the learner's current needs [12].

The majority of studies on AIEd have been carried out with university students. The meta-analysis by Wu, Huang & Hwang [13] did report on type of participant yet did not identify any with special needs. Given the potential of affect sensitive adaptive learning systems to provide personalised support, school-aged students with learning disabilities and autism were identified as a stakeholder group of the MaTHiSiS project [14] which aimed to use affective state and performance to drive the presentation of learning material in an adaptive learning system.

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For the project, a library of learning material was developed with teachers from the different schools. From this library teachers could create their own learning activities and learning graphs: an online equivalent of a specific lesson in traditional learning environments, where several learning goals are defined and are expected to be acquired. To reach these goals, the learning experience is divided into several Smart Learning Atoms, which are representations of small pieces of knowledge [14]. These reusable learning objects are self-contained learning components that are stored and accessed independently. In accordance with each atom's prerequisite atoms, they can be assembled and re-assembled into new learning graphs, or sequenced to form individual learning paths. For MaTHiSiS this level of granularity enables a higher degree of personalisation, as changes in affect detection can immediately drive changes in presentation of learning material directed by the learning graph. The long-term intention is that teachers will continue to develop their own library and learning materials to support the continued learning of their students and to cater for the wide variety of learners with whom they work.

Before a learner can start to use MaTHiSiS, their teacher must complete a profile detailing their characteristics such as age, gender, time in school, preferences and abilities. From these profiles, MaTHiSiS determines a starting level of challenge for whatever learning graphs the teacher has identified or constructed for them. As the learner works with MaTHiSiS, the selection and change in the learning content are based on their performance (calculated from correct and incorrect responses) and their affective state, maintaining them in an optimal affective state thereby maximizing their learning. MaTHiSiS requires a computer with Windows 8.1 operating system or above, a connection through the school's Internet or an external wireless portable router. This hardware enables initiation of sessions and upload of live data during sessions. Learning material can be displayed on the computer screen, an Android tablet, or a NAO robot. In addition to the accelerometer in the tablet, sensory data are collected from a Kinect V2 sensor and a high-definition web camera connected to the computer.

Developing such systems takes considerable investment in resources and, however much they may cost to buy and to maintain, evidence for their effectiveness is required before teachers can be expected to adopt them. In the field of health innovation, implementation science explores how interventions for which there is sound evidence get taken up and put into practice, identifying factors that influence uptake from all relevant sectors such as patient, provider and the broader community and policy environment [15]. The MRC framework for complex interventions [16] sees the promotion of effective implementation as the final phase in the development of an intervention, following the collection of evidence for effectiveness. However, there is a strong argument for considering implementation at the earlier stages of the process especially in the design of devices, technology or software. The widely adopted concept of user-sensitive inclusive design was formulated specifically to facilitate the design for heterogeneous user groups such as those with disabilities or the elderly, to ensure that the final product meets their requirements and adoption is more likely. Input from users is sought from the very start of the design process. In the words of Newell et al.

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[17] “Rather than suggesting that designers rely on standards and guidelines, it is suggested that designers need to develop a real empathy with their user groups” (p. 235). These authors emphasise the importance of getting the design right: “In a field where so many everyday needs go unmet, however, the idea of design that does not provide direct solutions may seem wasteful and self-indulgent” (p. 238). In the case of MaTHiSiS, though many researchers bought into this vision, challenges nevertheless arose from a disconnect between the classroom-based researchers who were scoping user requirements and the laboratory-based engineers who were designing the core systems. At least as far as MaTHiSiS’s use cases, to which this core system was to be applied, the design intention was that teachers and students should be involved from an early stage of the design process adopting the USERfit approach [18] to determine the user, task and environmental requirements for the intervention.

Studies from higher or mainstream education have already highlighted a number of factors that may hamper or promote the adoption of computer based or e learning (e.g. [19, 20]) although none specifically on AIEd. Few studies have explored barriers to adoption in special-needs teaching. From a review of the literature, Abed [21] concluded that the ability of computer technology to facilitate personalisation may be its crucial element, as studies with negative findings were those where personalisation was absent and this lack of personalisation would lead to abandonment of the technology. The review focussed on ICT’s potential to include students with special needs into mainstream classes; views expressed by the 20 teachers interviewed centred on the challenge of providing extra support for students with special needs who are taught alongside typically developing peers. The findings were not transferable to classes comprising only special needs students.

The review by Liu, Wu and Chen [5] identified 26 publications on technology in special education from 2008 to 2012 and found that although negative outcomes were reported much less than positive ones there were challenges to incorporating such technologies into the curriculum. These challenges had been highlighted in the study by Campigotta, McKewen & Demmens Epp [22] and included integration of such devices into the classroom, the effort required to populate the application with learning material and the limitations of the devices. Teachers may also experience time constraints setting up the technology, limited access to the necessary technology, and difficulties in managing the class.

Given the lack of information about barriers and facilitators to the adoption of e-learning for those with special needs, the present study set out to collect the views of teachers who were taking part in preliminary evaluations of the MaTHiSiS system. The information obtained was intended to feed back into the ongoing design process to enhance the probability that the final product would meet the needs of teachers and learners and thus improve its adoption. Such a user-centred product would also facilitate recruitment to a larger scale evaluation whence definitive information of the effectiveness of the intervention would be sought.

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The aim of the present study was to discover what teachers see as the barriers and facilitating factors to the adoption of an affect sensitive adaptive learning system for their students with learning disabilities and autism.

2 Methods

2.1 Design

Single semi-structured interview conducted either one-to-one or in a focus group.

2.2 Participants

Twenty-one (21) participants were recruited from the staff at schools and educational centres at six different sites (Nottingham and London in the UK, Rome, Salerno and Fumane in Italy and Valladolid in Spain) who had taken part in the development and evaluation of the MaTHiSiS system (for more detail see [14]).

2.3 Procedure

Before the study commenced, ethics approval was received from the first author's University Faculty of Medicine and Health Sciences Research Ethics Committee, B16122016.

After meetings between research staff and teachers at each testing site to explain this phase of the project, teachers who expressed an interest in taking part were given information packs and consent forms, and times and locations for the data collection were agreed.

Five focus groups of between two and four participants were held, but at one testing site a series of individual interviews took place as it was not logistically possible to organise a focus group.

If required, a brief description of the MaTHiSiS system was given at the beginning of the session to remind teachers of the different components of the system. A semi-structured interview approach was adopted and the topic guide, with prompt questions, was structured according to the four types of factors found by Minocha [23] to influence the adoption of social software. These are:

- social (e.g., issues related to collaboration and group working)
- educational (factors that have a bearing on learning and teaching)
- organisational (the way in which the institutions involved deal with the introduction and use of the tools)
- technological (factors related to access, implementation and maintenance of the tools and services)

The focus groups and individual interviews lasted between 20 minutes and an hour and were audio recorded, transcribed at the pilot sites and translated into English language. These transcripts were then sent to the UK partners responsible for carrying out the analysis.

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2.4 Analysis

Four members of the research team analysed the transcripts using thematic analysis following the stages described by Braun and Clarke [24]. First, all four members of the team independently read the same three transcripts selected because they presented particularly lengthy and detailed answers to the prompt questions. They assigned initial codes to sections of text relevant to the research aims and made suggestions how these might be combined to form an overarching theme. According to Braun & Clarke [24] (p. 82) a theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set. The team then met to discuss their potential themes and agreed an initial set of themes with clear definitions and names for each theme. Then each team member independently analysed a subset of three or four of the transcripts so that each transcript was analysed by at least two team members. A final discussion agreed an updated set of themes from the first tentative set and a selection of text extracts that vividly conveyed the meaning of each theme.

3 Results

The team of four researchers agreed on five themes that captured the teachers' views of the system's potential impact, especially regarding learning and engagement but also on factors that might influence adoption. The following five themes emerged from the analysis:

1. Transformative potential
2. Ability to impact learning outcomes
3. Potential impact on teacher-learner/peer-learning relationships
4. Ease of use/usability issues
5. Organisational challenges

References to original transcripts are made using the convention: (name of interviewing partner, page number), where:

UoN: University of Nottingham (UK)
NTU: Nottingham Trent University (UK)
RIX: Rix Research and Media from the University of East London (UK)
PE: Polo Europeo della Conoscenza (Italy)
JCYL: Consejería de Educación Junta de Castilla y León (Spain)
LCS: La Cometa del Sud (Italy)
FMD: Fondazione Mondo Digitale (Italy)

Participants are referred to in the results collectively as "teachers".

3.1 Theme 1: Transformative potential

Interviewees observed that the nature of the system might exert a long-term effect on their teaching practice in two ways. The first was on the way teachers saw their students,

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as use of the system revealed students' skills, knowledge and abilities that they had not otherwise understood or realised. The second was on the way they taught: the MaTHiSiS system was based on "non-linearity" (the ability to create learning experiences that are decoupled from the traditional progression of learning goals but that support highly individualised goal-oriented learning experiences), seen as very different to current classroom practice.

Changes in teachers' perceptions of students. Teachers had observed that use of the system revealed students' skills, knowledge and abilities that they had not otherwise understood or realised. Students sometimes had not been afforded the opportunity to show their true range of skills and abilities. The system allowed them to demonstrate these.

"Students (names) for instance demonstrated much more skills, than you would otherwise (realise) without the computer system. And also people/students like L. who seems very social and engaging but sometimes you think or maybe she, you know… but she was able to demonstrate what she can do, showing you much more than you would think." (RIX, P2).

The instances where this observation had been made arose because the support given by MaTHiSiS had allowed the teachers to relinquish a degree of control:

"I like it that there are certain activities where students can become independent. So, a lot of students I worked with probably might not have the confidence, or might not have the opportunity to, but I think now there are several of them from the group we had who would be able to sit and do this independently. And I think that's really important for the students but it's also important for the staff. I had to step back a little bit and let them do that. And I realised that they are progressing themselves as well" (RIX, P4)

This led to the realisation that maybe they should increase their expectations of the students' achievements:

"I keep going back to the sequencing with the lights, but that was my light bulb moment, that we don't push our students enough. We are not giving them a chance if they can't do it doesn't mean that they never do." (RIX, P11)

Changes in teaching practice. Interviewees found the whole notion of an affect sensitive adaptive learning system and the construction of teaching material that it required as something very different from their current practice:

"well, MaTHiSiS uses a quite different approach to teaching, compared to our system ... what you define "non-linearity" (the ability of MaTHiSiS to create learning experiences that are decoupled from the traditional progression of learning goals but that support highly individualised goal-oriented learning experiences), *"isn't that? Non-linearity is something completely different, compared to our methodologies*" (FMD, P3)

It would change the way teachers prepared lessons:

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"if I think to a future use of the system…well…I imagine that MaTHiSiS could help me with my job. I would prepare the lessons in terms of learning graphs, include the LMs I want… it would be a different way to prepare and plan the lessons" (FMD, P4) as well as allowing teaching staff to better share out their finite time between a large, probably heterogeneous, group of students:

"[I]f you have the chance that while you [students] are doing an activity that is appropriate to your level and you can be with others." (JCYL, P4)
or, for critical thinking and reflection:

"This would actually give staff more time to think critically, more time to develop really good learning materials for the students." (RIX, P6)

3.2 Theme 2: Ability to impact learning outcomes

Prompting interviewees to consider the educational implications of introducing something like MaTHiSiS revealed four sub-themes illustrating the way interviewees saw the potential impact on learning outcomes. These were: maximising engagement/minimising boredom and frustration; improved teacher knowledge of students' progress; empowerment of learners; impact on achievement and behaviour.

Maximising engagement/minimising boredom and frustration. Teachers were aware that this was the aim of the intervention but emphasised the importance to them of maintaining engagement in their students, especially so for those with ASD:

"… because "to be engaged" does not simply mean "to be there, to pay attention", it means to be prepared and to be willing to learn, it's related to motivation in my opinion and it's very hard to understand this with ASDs students." (FMD, P1)

The ability of MaTHiSiS to detect and use information about affective state was described by one teacher thus:

"An increased concentration and opportunity to achieve something is greater. Rather than getting frustrated and giving up the student is more likely to stay engaged and learn for longer – because of the adjustment to the level. So the student will be engaged for longer. And I would hope that because of this the child will be able to learn more." (RIX, P1)

Additionally, teachers appreciated the feedback they could obtain about their student's affective state:

"The monitoring of the learner has been shown to PE02's teachers and I think that this can be a support for them since they can check the level of motivation and the level of not… where is absent the boredom in a certain activity, if this will be generalised to the traditional school activity, the school activity can be more effective in terms of learning for the student" (PE, P2)

Improved teacher knowledge of students' progress. Teachers commented that MaTHiSiS facilitated enhanced tracking of student progress:

"And also having the data and seeing them really progressing I think it's fantastic for staff." (RIX, P3)
and this knowledge could be used to personalise their learning pathways:

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"The MaTHiSiS system has lots of potential for teachers to know their students much better and understand their level and provide materials that are suitable for them and stretch them." (RIX, P4)

The particular monitoring that MaTHiSiS provided was seen as especially useful in special education where student progress was better seen in terms of small steps:

"Because in mainstream you have your levels, whereas in special needs it's really hard to assess the little jumps but it's really important to assess the little jumps" (RIX, P3*)*

Empowerment of learners. Teachers described their students as having begun to construe themselves as actors in their learning experiences and hence having achieved some sense of control over the learning process.

"The other learner was a very severe PMLD I think that his involvement has been reached when he started to perceive himself as able to perform an act, in his case to touch, to be able to give the correct answer in a physical way." (PE, P1)

Impact on student achievement and behaviour. Teachers reported several benefits for their students. In common with other computer mediated learning, the opportunities for frequent repetition had noticeable benefits for some students:

"I think repetition…. Repetition [of learning material] is very useful for ASDs students especially with new things to learn. For example, E cannot read as you know, he [pause] memorizes the words as images. With MaTHiSiS I noticed that he started to memorize new words as the [learning material] appeared again!" (FMD, P2)

And that while this learning took place using a specific system it could generalise:

"Yes, definitely, like I said, it has the real potential for generalising learning to another situation" (RIX, P9)

Some teachers noticed an effect on terminating disruptive behaviour and exploited this:

"....so actually you could send – if they are getting to that point where they're disruptive, "Tell you what, would you like to go and do a bit of MaTHiSiS in the corner... And actually then they're still hitting learning objectives, they're still learning." (NTU/UoN, P18)

3.3 Theme 3: Potential impact on social relationships

Even before the remote learning imposed by pandemic precautions, the role in learning of social contact had been recognised. When considering the impact of a system like MaThiSiS, interviewees highlighted the importance of relationships between teacher and student, between students but also between the school and family.

Teacher student relationships. MaTHiSiS was never intended to be used without supervision yet strong views were expressed that such a system could never replace a teacher:

"If we are talking of a model that foresees the disabled child alone in front of a screen or a robot, I'm completely against this idea." (PE, P3)

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In support of this, participants highlighted the role of emotional closeness to facilitate the learning process and that this was something only a human teacher provided:

"*The emotional closeness is very important more than fundamental, the child is reassured by the presence of the adult. Personally I use the emotional closeness in my profession, in the formal learning situation and in the group activity because it's a condition that eases the learning process. The machine, the computer, in short, technology can support what is the help and therefore what the adult can do to get to the development potential of each student. The machine can support this, but I do not think it can be substituted"* (PE, P5)

Participants also stressed the need for interventions to avoid frustration, although the system was specifically designed to do just this:

"I needed to be side by side with the pupil in order to favour learning without error, since he gets very frustrated with failures." (JCYL, P6)

While the system was designed to utilise machine learning to recognise patterns in noisy data using a series of features (for instance eye gaze, body posture, facial expression) across a large sample of users and then making predictions and inferences, teachers were not always confident this could reliably match the sensitivity of a human:

"*If we are talking about decision-making, I believe that an algorithm can never substitute the human eyes and the ability to feel the child's emotion that a teacher develops in the relationship with the pupil. A system can provide hints, and can be useful in a group condition – when the whole class is working and the teacher cannot follow the progression of all. But with the disabilities or the autism we are working in an individual way, sometimes the change of the affective state is so slight and depends on the individual and unique expressions of the child that only a teacher that knows him very well can interpret."* (PE, P3)

It was also felt that the salience of different channels varied between children, especially for those with very limited physical ability:

"You have to get to know them sometimes as well to understand that yeah, they are, brain, motor skills, it's all there, but sadly they can't use their arms, their legs, they can't get that across with anything other than eyes and head." (NTU/UoN, P6)

Likewise, informativeness of various channels varied for users with autism, corroborating findings that many individuals with autism in many situations will use gaze aversion as a strategy to manage cognitive load, and actually can think better when they are not looking at the object of their attention [25, 26]:

"And the one thing interestingly enough about the eye gaze, tracking eye movements, I think it's interesting because – but then sometimes I think children with autism may not actually give you the most accurate data in that sense. Because I've got a child in my class who will just not look at what he's doing, no matter what." (NTU/UoN, P6)

Because of these differences between autistic and non-autistic learners, and also heterogeneity within the broad rubric of the autism spectrum, the within-subjects evaluation of MaTHiSiS raised a question as to whether affect detection and its precise role in determining the presentation of learning material, may need to take a different form for learners with autism [14]. In spite of reservations, teachers recognised that the technology had the potential to act as a 'social mediator' between themselves and students, especially those on the autistic spectrum:

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"yes, using the system could help a new ASD student to gradually know and meet the teacher, you know? To reduce his/her anxiety with new people" (FMD, P6)

Teachers acknowledged that the nature of their relationship with the learner would change but primarily in the type of interactions they had and how they targeted their support:

"I don't have any worries that the robot takes away the role from the teacher, but the way technology is going it's good if technology could help with some of the decision making and we can support learners that need that support and others might be working away with our support" (RIX, P6)

Student-student interactions. Some collaborative scenarios had been developed for the system whereby two students could work together taking it in turn to make a move or a choice. However not all centres had access to these. Those teachers who did experience them welcomed the introduction of the collaborative scenarios which scaffolded constructive social interaction (see [27]):

"Collaborative option - it is really nice, there are few things, you know, the students wanted to interact with me, especially the monsters and the mazes and things like that. They were trying get me involved and I would say 'that's your maze, carry on' but if they were actually doing it together, supporting each other or racing against each other to do it, or something, that would be very nice social activity and learning, building confidence and having fun" (RIX, P9)

Special attention should be given to the selection of collaborating partners:

T1: "Yes, but with students who have similar characteristics or difficulties or development."

T2: "It is good to make them progress in a similar way, but you can also use one or two children from the class and let them be the helpers."

T3: "Yes, but you have to select them very well. Otherwise they will not help they will answer instead of him". (PE, P5)

Parent's involvement with their child's education. The positive effect of parental involvement in a learner's progress is well known but difficult to achieve especially in special education. Teachers saw the potential of using the analytics engine of MaTHiSiS (e.g. graphs of affect state and learning progression) as a medium for sharing student progress with their parents or caregivers:

"For me the graphs of each student… have been very useful. I'm thinking of showing them to the parents in order to let them know about their children's work at school. Also collaborating with the class teacher showing her these results will be interesting." (PE, P2)

3.4 Theme 4: Ease of use

A range of characteristics of the system impinged on the ability of both teachers and students to use it with ease. Teachers recognised that they were participating in a research project and that the system with which they were working was still in

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development but raised several points which were crucial in promoting the adoption of a system like MaTHiSiS.

The need for training and support. Teachers welcomed the training that they had received in using the system at the beginning of the evaluation phase but thought that this on its own was not enough to support adoption. What was needed was ongoing training rather than purely initial training and support:

"[T]he equipment, and probably the staff taking it on as well, as it would be something else new and sometimes that quite scary and daunting, and even though they had the training it still doesn't get adopted by staff. So I think that would be the main barrier." (RIX, P5)

Time investment. At the beginning of the evaluation phase, teachers had access to a selection of learning material that would be suitable for their nominated students for the period of the evaluation. For ongoing use, though, they would need to develop more learning material to ensure all lesson plans could be fulfilled by the system. This investment in time was seen by some as daunting but could be offset by a range of other aspects of the system.

For example, once produced, material could be reused:

"In theory the possibility to reuse the material can quicken the preparation work." (PE, P2)

And shared between teachers and between schools:

"But I think that means you could distribute it across the – like encourage other people to take on the software and if they took it on as well, then you would say – right, what about this? What about that?" And – *"It's like teachers always are little magpies, we take things off each other all the time, we take ideas – Oh, can I just – I found this online the other day, and just bring it over to someone."* (NTU/UoN, P30)

In addition to time saving from the reusability of learning material, teachers' time could also be freed through the support to students the system provided. This assistance would give teachers time to attend to more vulnerable learners and to other critical teacher roles such as developing appropriate learning materials:

"I think once the teacher got used to using it, I think it could definitely save them time. I think initially, they might not notice the difference but they have realised what it was able to do then it would give them more time to prepare other things and create other activities in the classroom, definitely." (RIX, P11)

Accessibility for learners. As far as student use was concerned, there was definitely a feeling that some groups would be able to use the system with minimal support:

"*I mean, like I say, students with autism, I think they'd need help to start with but then they'd be able to do it straightaway. I mean, students with more severe learning – you'd probably always need a staff member with them, depending on how severe their learning need was*." (NTU/UoN, P24)

Teachers made it clear, however, that for some students, there remain motor (physical) and cognitive barriers to using the system. These obstacles are functions both of the core system and of the learning materials developed for it:

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"*Pupils need to have a minimum cognitive ability (too deep PMLD maybe it is not fine), apart from having good motor skills. Here we are working with children that had limited mobility to interact with the tablet. It's also a barrier that they (pupils) have not yet acquired reading skills, although I could solve it by reading them the words or texts*." (JCYL, P2)

3.5 Theme 5: Organisational challenges

Teachers' views on possible constraints to adoption alluded to the physical environment and the organisation's current practices and to attitudes towards the introduction of such a system.

School environments. Environments have been designed and organised to enable the predominant teaching practice of the time. For many, the organisation of the physical environment would need rethinking.

"It's not even the behaviour, it's just some of the – it's just manoeuvring wheelchairs around the classroom as well, you've got that, and some classrooms are bigger than others. Thankfully I've got quite a big classroom now but there are some classrooms where you're manoeuvring wheelchairs and equipment might just not fit in that room." (NTU/UoN, P19).

However, some teachers face an even bigger challenge in the inadequacy of the school's technology infrastructure:

"We have worked with quite 'precarious' conditions, I mean, in the school we do not have too nice WiFi conditions, when we change to the other building, with nice and speedy WiFi connection I think it would be easier. It is clue to have a good Internet connection and also nice devices." (JCYL, P4)

Fitting into existing practices. One challenge is the need to sustain a system that is set up for one learner while having to cater for the needs of a whole class. Teachers had varying opinions on whether they could run MaTHiSiS on a whole class basis:

"But you couldn't do it as a whole class setting could you really, because the sensors would have to be on every child and you wouldn't – it would be a huge thing. It would have to be like a lab full of the same sensor. And I don't know whether a school would buy into that because it would be a lot of money I'm assuming (laughs). So it's kind of a case of on a one to one target level I think it could work." (NTU/UoN, P14).

Introducing new technology was felt to be challenging if some colleagues were resistant to change:

"Yeah, so I think in terms of a lot of those things would put up a barrier in some teachers' heads to begin with, particularly with the organisation of it. I think it would take a while to get people in the MaTHiSiS way, that it became a thing in the school. It would be like eventually it could be really useful, but the organisation of it would probably – when people are rushing around there's just no time: I can't do it, there's just no time. I don't want to do it in my time." (NTU/UoN, P16)

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This reluctance was even more marked when it came to embracing digital technology in their teaching practice although this was seen to be a characteristic of the older generation or those who had not encountered IT during their training:

"There are certain teachers… who don't want to do anything IT wise, ICT wise, that might be too advanced for a teacher maybe. They think it's too advanced for themselves but it isn't. And they're just not open to new things. Whereas I think you'll find that maybe the younger generation of teachers, or teachers that might not be younger generation, but they might not have been a teacher, they might have qualified late, they're just maybe open to things like this more." (NTU/UoN, P16)

School budgets. If schools did not already have access to the components of the system, initial set up costs seemed daunting:

"Well… no! [laughs] as T1 said, we don't know the cost of the system, so… let me think… I imagine that MaTHiSiS is going to be quite expensive, right? Because it's a new system, because of its complexity etc. Not to mention the costs of the equipment!" (FMD, P8)

However, although the costs of equipment were often seen as high, they were offset by longer-term gains:

"If you have to buy the laptop, the tablets, put a high speed WiFi network ... this is an economic investment that, although it is profitable in the long run, it is not easy." (JCYL, P9)

If any colleagues were still reluctant to adopt such a system, one participant felt the crucial argument would be the cost-effectiveness of a system that could reliably interpret student engagement:

"So something that's measuring their engagement, all that sort of pressure, oh gosh, what if this child doesn't listen and learn because he never does it in lessons, they're going to find out. Whereas actually if you put them on a software where you know they're going to engage, you know that the software is measuring their engagement, I can't see how that wouldn't be a successful argument. In a situation where they're trying to balance cost effectiveness." (NTU/UoN, P34)

4 Discussion

Given the slower rates of adoption of computer-based learning in special education, the intention of the current study was to elicit the views of teachers on factors that would influence implementation. Resolving these factors at an early stage in development was considered important in order to modify the design in ways that would make adoption more likely. In spite of being highly motivated by virtue of having volunteered for a research project, teachers highlighted a range of issues that need addressing in order to promote adoption of this type of technology. There were design issues such as accessibility for learners and accuracy of the algorithm but these had been largely addressed by the time these final interviews took place (although affect detection and its precise role in determining the presentation of learning material, may need to take a different form for learners with autism). This experience underlines the importance of involving end users directly in the design and development process. Of more interest

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are the factors on which implementation depends but which are usually considered to be outside the designer's remit. These factors operate at an individual (teacher) level (e.g. the potential of the system to transform the way they worked) or at an organisational level [28].

An expensive technology-based intervention must be seen as worth the initial outlay in training, purchase of equipment and development of teaching material. Teachers were acutely aware of the educational advantages enabled by the technology which may be strong enough for initial adoption. However, they frequently referred to the investment in time required not only to prepare material but also to rethink the way the system could be incorporated into their day-to-day practice, a factor also identified by Campigotto et al. [22], Basak [19] and Cox et al. [6]. They cited organisational barriers such as the budgets, reluctance of colleagues and the school environment. Some of these factors have been highlighted in implementation science and by the researchers cited above. For perceived advantages in pedagogic practice and educational outcome to outweigh the perceived disadvantages in retraining time, financial outlay, environmental restructuring and organisational inertia, teachers need to be assured that these would be offset by longer-term savings in both time and financial investment.

However, of equal importance to these barriers to adoption are the factors that promote ongoing use. Teachers need ongoing support. Additionally, they need time to reflect and plan: to rethink their lesson plans, to share material with others and to engage and solve organisational issues. Developers can anticipate these challenges and should make every effort to not only address usability issues (including the ease with which teachers can input and update their teaching material) but also to design approaches for ongoing training and support as well as keeping component costs low.

Teachers are not the only stakeholders who determine the adoption of a new technology or other practice. Students and their families also have a perspective as do local managers and educational policymakers. At this stage of development of the MaTHiSiS system, teachers were the group that had the most experience of it and could also provide their observations on the other perspectives. If such educational technologies are to succeed practically, future research should involve other stakeholders to ensure barriers at all levels are identified.

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