

MULTI-MODALITIES IN CLASSROOM LEARNING ENVIRONMENTS

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Abstract

This paper will present initial findings from the second phase of a Horizon 2020 funded project, Managing Affective-learning Through Intelligent Atoms and Smart Interactions (MaTHiSiS). The project focusses on the use of different multi-modalities used as part of the project in classrooms across Europe. The MaTHiSiS learning vision is to develop an integrated learning platform, with re-usable learning components which will respond to the needs of future education in primary, secondary, special education schools, vocational environments and learning beyond the classroom. The system comprises learning graphs which attach individual learning goals to the system. Each learning graph is developed from a set of smart learning atoms designed to support learners to achieve progression. Cutting edge technologies are being used to identify the affect state of learners and ultimately improve engagement of learners.

Much research identifies how learners engage with learning platforms (c.f. [1], [2], [3]). Not only do e-learning platforms have the capability to engage learners, they provide a vehicle for authentic classroom and informal learning [4] enabling ubiquitous and seamless learning [5] within a non-linear environment. When experiencing more enjoyable interaction learners become more confident and motivated to learn and become less anxious, especially those with learning disabilities or at risk of social exclusion [6], [13].

[7] identified the importance of understanding the affect state of learners who may experience emotions such as 'confusion, frustration, irritation, anger, rage, or even despair' resulting in disengaging with learning. The MaTHiSiS system will use a range of platform agents such as NAO robots and Kinects to measure multi-modalities that support the affect state: facial expression analysis and gaze estimation [8], mobile device-based emotion recognition [9], skeleton motion using depth sensors and speech recognition.

Data has been collected using multimodal learning analytics developed for the project, including annotated multimodal recordings of learners interacting with the system, facial expression data and position of the learner. In addition, interviews with teachers and learners, from mainstream education as well as learners with profound multiple learning difficulties and autism, have been carried out to measure engagement and achievement of learners. Findings from schools based in the United Kingdom, mainstream and special schools will be presented and challenges shared.

1. INTRODUCTION

Multi-modality information is increasingly being used in software development particularly for learners with profound intellectual and multiple learning disabilities (PMLDs) who typically show limited communicative abilities, particularly with respect to spoken language, or the use of augmented or conventional assisted communication. This paper presents findings from the second phase of a 3-year Horizon 2020 funded project, Managing Affective-learning Through Intelligent Atoms and Smart Interactions (MaTHiSiS).

This paper focusses on the use of different multi-modal data used as part of the project in classrooms across Europe with learners with PMLD, autism or in mainstream education. The paper contributes new knowledge related to the use of multi-modal data in learning in school classrooms using a variety of platform agents, connected through one learning platform: MaTHiSiS.

The MaTHiSiS learning vision is to develop an integrated learning platform, with re-usable learning components which will respond to the needs of future education in primary, secondary, special education schools, vocational environments and learning beyond the classroom. The system breaks down a learning session into a learning experience which comprises of 'learning graphs' and 'learning materials' which attach individual learning goals to the system. The learning graphs are simply finite state machines (FSMs) that transition the learners through the learning materials – given the node's condition satisfaction. The learning goals related to Bloom's hierarchical Taxonomy [10, 12]: remembering, understanding, applying, analyzing, evaluation, to creating. Each learning graph is developed from a set of 'Smart Learning Atoms' (SLAs) designed to support learners to achieve progression¹. Learning materials can be adapted from existing content or newly created. Learning graphs and learning materials are created in a tool called the 'learning content editor' in MaTHiSiS. Cutting edge technologies are being used to identify the affect state of learners using multi-modal sensory data and ultimately is used to improve the engagement and progression of learners within the MaTHiSiS system.

Much research identifies how learners engage with learning platforms (c.f. [1], [5], [2], [3]). Not only do e-learning platforms have the capability to engage learners, they provide a vehicle for authentic classroom and informal learning [4] enabling ubiquitous and seamless learning [5] within a non-linear environment. When experiencing more enjoyable interaction learners become more confident and motivated to learn and become less anxious, especially those with learning disabilities or at risk of social exclusion [6].

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The MaTHiSiS system provides an integrated cloud-based interactive learning space with personalised and adaptive learning components, data acquisition and analysis. The system enables two types of users: tutors (instructors or carers) and learners (dependent or independent). Each user has a distinct role within the system; for example, the tutor can create learning graphs with existing or new learning materials, identify appropriate learning goals, set the difficulty level individual learners are working towards and assign different platform agents (computers, interactive whiteboard or robotic agents) to deliver the learning. The system's main aim is to ensure a constant learning flow, augmented learner engagement, affect state recognition and deliver a comprehensive analysis of learner progress for tutors. Various devices can use the system such as robots, mobile devices, desktop computers and interactive whiteboards. The system is being developed collaboratively with pedagogical experts, school teachers and technical partners.

To personalise the learning experience, the teacher can input learner profiles for individual students with information relating to any learning difficulties, physical impairments, etc. Each learner has a unique ID. When the learning session (lesson) takes place, the teacher selects the Learning Graph which is appropriate for the lesson and a competence weight for each smart learning atom (SLA) is based on the individual's learner information. As the learners interact with the system, multi-modal data captures affect (emotional) behaviour information of students. The MaTHiSiS system then processes the affect behaviour, updates learner's competence for all or some of the smart learning atoms derived from their achievement and provides an achievement score for each learning goal which the teacher is then able to review and then decide to increase or decrease learning goals for individual learners. The teacher also receives data on the learner's affect state. At the end of each semester/term the teacher can produce a summary report on achievement of learning goals and competence scores.

¹ Small learning atoms are a complete piece of knowledge that can be learned and assessed in a single short-term iteration.

A first phase of data collection, a driver pilot, was carried out in school across Europe to test the different multi-modalities and ensure data collection in March-July 2017. Following this, methodologies were developed to ensure scenario-related features for affect (emotion) and cognitive learner responses, while interacting with learning materials, could be measured. As part of this process platform agents' (PAs) actions such as NAO robots, were challenged at various levels imposed through different use cases: mainstream, PMLD and autism. At this stage, the complexity of the environment (number of smart learning atoms involved) and parameters were defined relating to overall difficulty and relevance to the learning goal. Consequently, different scenarios and interactions were developed sharing common descriptions, so that they could easily be re-used or replaced, without requiring further system re-training in terms of adaptation and personalization. This re-usable quality of learning content in its simplest form, is proposed as one of the main advantages and novelties of the MaTHiSiS system.

In Phase 2, reported here, an assisted pilot was carried out using mainly the same schools as in Phase 1. Prior to the assisted pilot teachers were trained in how to use the system and the different PAs. It was expected that teachers would be able to use the system with some (assisted) support from the technical team.

The multi-modal sensory features within the MaTHiSiS system are:

- Facial expression analysis and gaze estimation² for estimating user responses and affect related to events and learning content: user engagement [8], in this sense, will be a prioritised state to retrieve in MaTHiSiS. For some learners such as those with autism and PLMD this modality will be measured using human-robot interaction.
- Mobile device-based emotion recognition: inertial sensors (accelerometers) embedded in mobile devices will be used in the context of MaTHiSiS for analysing user engagement or frustration. MaTHiSiS will make use of preliminary works in the field [9] and will determine generic and person-specific expressions linked with arousal.
- Skeleton motion using depth sensors such as Kinects³: information related to affective cues in applications where body posture conveys affective content (human-robot interaction / interactive whiteboards).
- Speech recognition and speech-based affect recognition: this modality focuses on detecting spoken words using a limited-vocabulary setup. In addition, verbal cues will be employed in order to extract estimates of the user's emotional state that will supplement the rest of the affect state analysis based on other modalities and devices.

The MaTHiSiS platform will enable affective state measurement using these affect sensing technologies such as webcam, NAO robot, Turtlebot, Interactive Whiteboard or Kinect. The MaTHiSiS system will identify the affect state by:

- tutor annotated multimodal recordings featuring learners' attributes while interacting with the system;
- facial expression data taken from MaTHiSiS sensorial component (including autistic and PMLD learners);
- position of the learner (using GPS, QR codes, etc).

Learners in the project are in primary (aged 3-11) or secondary schools (aged 11-19). There are also learners in careers guidance or working in industry but these are not reported in this paper.

2. METHODOLOGY

This phase took place September to December 2017. The pilots took place in the UK, Italy and Spain. Seven schools took part with 16 teachers, 64 learners and 17 tutors. The schools were:

² <http://www.tobii.com/>

³ <http://www.microsoft.com/en-us/kinectforwindows/>

- UK
Nottingham Bluecoat Academy
The Trinity Catholic School – Nottingham
- Italy
IC Rita Levi Montalcini School – Roma
I.C. Leonardo da Vinci – Bussolengo (Verona)
I.C. Don L. Milani, Sommacampagna (Verona)
Primary School I Circolo Cava De' Tirreni (Salerno)
- Spain
CEIP Joaquim Diaz – Valladolid

Prior to the start of Phase 1 data collection, ethical consent was gained following each country's guidelines. Informed consent was gained from all learners and teachers taking part in the data collection. Prior to the focus group interviews ethical consent was gained which included recording of the interviews.

Data was collected using multimodal learning analytics developed for the project, including annotated multimodal recordings of learners interacting with the system, facial expression data and position of the learner. In addition, focus group interviews with teachers from the United Kingdom (UK), Italy, and Spain from mainstream education and those teaching profound multiple learning difficulties and autism, have been carried out to measure engagement and achievement of learners:

Number of teachers/tutors	Type of learner	Country
3	Mainstream	UK
4	Autism and Visual Impairment	Italy
3	Mainstream	Italy
3	PMLD	UK
4	PMLD/Mainstream	Spain

In addition, one teaching assistant in the UK took part in a focus group interview.

Each interview was translated (where needed) and transcribed. A thematic analysis was then carried out using the process described by [11]. Initial codes were identified, and from these themes were developed.

Fifty questionnaires were also completed using an online form: 18 from mainstream, 13 from PMLD and 19 from autism education. Of these 26 were completed by teachers/tutors, 18 were completed by project observers, who had observed at least one teaching session where MaTHiSiS was being used, and 6 who classed themselves as 'other', who were mainly from the technical team.

RESULTS

At the start of this phase teachers and learners' expectations were high. Teachers were particularly interested in how using multi-modalities would provide data on the affect state which would facilitate an individualised learning experience.

Questionnaire

From the questionnaires, 15 tutors indicated that the system enabled the learners to achieve individual learning goals; 28 felt the system probably enabled learning goal achievement; only 6 felt it had not helped.

Thirty-one of the respondents stated that the MaTHiSiS system did increase the engagement of their learners, 15 thought 'maybe' and 3 said it had not helped.

Over half of the respondents found the system easy to use, with 21 finding it challenging. Twenty-four respondents had found it difficult to create the learning graphs and learning content editor; comments included 'mainly the creation of the materialisation for all the platform agents, the setup of the clients for the sensors and the platform agents' thus indicating the sensors required for the multi-modality data may be too time-consuming to set up for individual lessons, therefore schools may need to consider having classrooms with PAs set up for teachers to use, thus reducing the time required in set up. Twenty respondents indicated they had reused learning materials. However, one teacher commented 'I dedicated too much more time on creating a simple LG than the time I dedicate to organize usual learning plans' indicating that there is a need for further training. However, as the online library grows teachers should be able to adapt existing materials, thus reducing their preparation time.

Respondents had mainly found the data from the system relating to the affect state, measured by the multi-modal sensory data very helpful. Of the respondents eleven found their learners became disengaged when re-using SLAs; this is an important finding from the multi-modal data provided by the system on the point at which a learner disengages, therefore for the learners who became disengaged the teacher has learnt the importance of providing original SLAs to ensure they remain engaged.

The majority of respondents found the system could be used for mainstream, PMLD and autism spectrum children. Only 8 said this was not possible; their comments suggest this is due to the system rather than the multi-modality approach: 'some children would find impossible to hold a tablet, interact with a PC or hold cards in front of the robot without assistance', 'pictures on screen were very small', 'for the children with fine motor skills deficit it's too complicated to select the correct answer'.

3.1 Focus group interviews

The respondents who took part in the focus group interviews stated that there was improved motivation and engagement. Teachers also commented that learners wanted to know what their affect state was from the data provided as well as how they had achieved their learning goal. Affect state data is not available on any other learning platform. While it was expected teachers would find this highly useful in designing appropriate learning materials and in supporting the achievement and progression of learners, it was not anticipated that learners would find the data provided by the utilisation of multi-modal data, this unexpected finding will be of interest to teachers globally. It was identified that autism spectrum learners were particularly interested in the data of their affect state and level of achievement. Whether this new data will continue to engage and motivate learners over repeated sessions will be reported in the final phase. Further evidence of improved engagement was provided by teachers whose learners were very keen to know when they would be using the system again.

Persistence was frequently commented on by respondents. Respondents welcomed the data provided from the multi-modalities and the value of a learning platform that provided data on persistence was recognised. One teacher commented ". . . most children will stop at the first block, the first hurdle. So what you're really looking for is them to carry on and try to solve problems... (NTU, p. 22).

Respondents also commented on the benefit of being provided with affect state data of when individual learners became bored and stopped learning. They recognised that some children need to reuse materials to enable them to learn, while others became disengaged when presented with similar learning materials. The data provided via the system, notifying the teacher at what point an individual learner became disengaged was seen to be highly important in a student centred learning environment. Respondents also commented on the potential downside of students' being able to see the fluctuations in the state of affect, particularly signals of decreasing motivation or engagement: "Their progress might say they're going down" (NTU, p. 25) with the implication that such moment-to-moment feedback might further demotivate them.

Teachers observed that MaTHiSiS can facilitate reflection on how knowledge of a student's affect state informs teaching and learning: "For a teacher the experience of using MaTHiSiS is useful to

reflect on learning and teaching personalisation, based particularly on the state of affect. I'm talking about a methodological reflection. Also, the use of innovative tools supports the teachers developing new pedagogical student-centred approaches, based on non-traditional tools" (FMD p. 8; LCS). A PMLD teacher commented that the affect state recorded by MaTHiSiS will be useful in itself for recording a student's progress: "I'm just thinking in terms of our assessment tool which is Classroom Monitor, a lot of the things we're doing at the minute, a lot of their targets are engagement and things like that, so I'm just thinking this sort of fits in with a lot of – so can they engage for up to one minute or – and things like that (UoN, p. 11).

4 CONCLUSION

This paper set out to report the second phase of a 3-year research project which aims to develop an integrated learning platform as a collaboration with pedagogical experts, school teachers and technical partners. The paper set out to evidence how multi-modal data is being utilized to provide affect state data for teachers of PMLD, mainstream and autism spectrum learners. This pilot indicates that the use of multi-modalities can enhance the learning experience of learners in mainstream education and learners with a range of learning difficulties which may be profound.

Acknowledgements

This paper reports findings from a Horizon 2020 funded project (Contract 687772). We acknowledge the support of colleagues involved in the project from Nottingham Trent University (UK), University of Nottingham (UK), ATOS Spain, University of East London (UK), Polo Europeo della Conoscenza (Italy), Consejería de Educación_Junta de Castilla y León (Spain), La Cometa del Sud (Italy), Fondazione Mondo Digitale (Italy). We also thank the children and teachers at Nottingham Bluecoat Academy (UK), The Trinity Catholic School (UK), IC Rita Levi Montalcini School (Italy), I.C. Leonardo da Vinci (Italy), Bussolengo (Italy), I.C. Don L. Milani, Sommacampagna (Italy), I Circolo Cava De' Tirreni (Italy), Miguel De Cervantes (Spain).

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