HOW TO EVALUATE THE SUCCESS OF NOVEL LEARNING TECHNOLOGIES: A NEW MODEL FOR ENSURING EARLY ADOPTION IN THE CLASSROOM

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Abstract

There is a clear disparity between the technology that we have at our fingertips, and that we use in our daily lives, and the adoption of that technology within our schools and our classrooms. Although we have seen some success when it comes to the integration of technologies into mainstream learning, there is now an increasing gap between the technological lives of young people and the learning experiences we can offer them. The problem, it seems, is not the availability of the technology but rather the translation of that technology into a learning context.

Part of the blame lies with the way in which we assess or evaluate the impact of new technologies before they reach the classroom. European businesses, and the European Commission, invest billions every year in the development of new learning technologies and yet comparatively few of these technologies ever end up in common usage in our classrooms. If teachers fail to adopt new technologies – or if students lack enthusiasm, engagement or connection with those technologies, this should be identified early on and remedies designed to address these issues.

The NEWTON Project, funded under Horizon 2020, is developing a new approach to Science, Technology, Engineering, and Mathematics (STEM) learning that is based on the adoption of a range of new learning technologies (including augmented reality, virtual reality, Fab Labs, multi-sensory learning and gamification). As the project moves into the pilot phase, we are now setting out our approach to evaluation and impact assessment.

In this paper, we present our evaluation model. This model is an attempt to succeed where others before us have failed. The model considers a range of different aspects to impact assessment that, we believe, will tell us which technologies are likely to be adopted in the classrooms and laboratories of our schools and colleges across Europe.

Our model focuses on three fundamental elements: first, we look at knowledge and skills acquisition. What is the extent to which these new technologies have a genuine impact on the educational development of students and how can we prove that this is the case? Second, we look at student engagement and student motivation. What we know is that a more engaged, motivated student is likely to be a better learner. Our approach seeks to measure the level of engagement and motivation and demonstrate the impact this has on learning. Finally, we explore the impact of the technology on teachers. How far do teachers embrace these new technologies? To what extent do these approaches make their teaching more effective? What are the barriers that might stop early adoption of these technologies within a classroom setting?

ICT can support the development of our model (and consequently the whole evaluation process) by providing correct methods to implement above each element. In detail, the model makes leverage on using learning analytics methodologies and techniques in order to analyse data collected during teaching and learning processes that are useful for better understanding students (and teachers) behaviour and the context (and settings) in which they learn (or teach). In this way, it is possible to constantly monitor the educative process and guarantee a precise evaluation and impact assessment.

Although this is a field that has a long history across Europe, impact assessments are too often designed without rigour and with an aim to simply provide “good results” rather than as a way of genuinely tested whether an educational approach actually works and is feasible for adoption in a wide range of learning settings. In presenting our theoretical model, we invite contributions from others who are similarly charged with assessing the impact of their learning technologies.

Keywords: learning, evaluation model, NEWTON Project, impact assessment.
1 INTRODUCTION

The way in which we learn, and the way in which that learning is taught, is changing rapidly. As globalisation begins to shrink the economies of the world and competition between nations, regions and continents becomes ever more fierce, the so-called ‘skills race’ is now, more than ever, real. Barack Obama once said “countries who out-educate will out-perform”. This recognition has pushed the way in which we learn, and the outcomes that we achieve, to the forefront of the political agenda. Successful economies are those that are able to educate and train their citizens in a way that is both inspiring and effective. Within that context, the need to ensure a steady stream of talented scientists, technologists, engineers and mathematicians is critical. Many of the most successful businesses of the last 20 years have been built by graduates of a STEM education1 and the importance of creating a foundation of STEM skills amongst tomorrow’s entrepreneurs and innovators is widely recognized.

The pressure to develop the skills, competencies and talents of a new generation of STEM citizens is set against the persistence use of many of the outdated 20th century models of didactic education that are failing to engage students and are ineffective in developing the range of skills required for a dynamic, well-educated population. However, we are beginning to see the mainstreaming of a range of educational models and pedagogies that challenge the orthodoxy of 20th century ideas about how we teach and learn. Moreover, central to this shift has been the increasing role of technology within education.

Although technology offers us significant potential in terms of engagement, motivation, skills development, experiential learning and so on, there is, we believe, a mismatch between the level of technological innovation that we are seeing in our general day to day lives and the degree to which technological innovations are finding their way into our classrooms. The reasons for this failure of uptake are varied (and the level of uptake varies from country to country and, in some cases, school to school). However, there is certainly one aspect of how we see technology within a learning context that is holding back the best ideas from becoming real world solutions – as with any innovation within education, it is vital that we prove that educational technologies actually work. This may sound obvious but we know that all the key stakeholders who influence what and how we teach – from parents and teachers through school leaders and up to ministers of state – are highly demanding if proof that any new educational intervention works. This is even truer of innovations based on technology, as educational stakeholders are inherently conservative in their approach to new technologies. Things may sound great in theory but if you cannot prove impact and efficacy, your brilliant educational technology will not be adopted.

The focus of this paper is to explore how we can develop a more complete and coherent model of evaluating education technologies and to share this as widely as possible. Too often, researchers and technologists pay lip service to affect evaluation whilst failing to implement a robust approach that demonstrates impact in a way that educators can believe in. The model we put forward in this paper, which we are developing as part of the NEWTON Project (more of which below), seeks to address shortcomings in existing models in order that the best learning technology innovations can be proved to be of real value. If we can do this, we will address the mismatch between the technology we use outside of the classroom and that which we see inside the classroom.

2 LEARNING EXPERIENCE AND NOVEL TECHNOLOGIES

At its best, technology can provide learners with compelling, relevant and highly experiential learning experiences that engages, motivates and achieves success in terms of learning outcomes that traditional models of learning can only dream of. The didactic approach to teaching and learning that emerged from the industrial revolution and persisted during much of the 20th century was based on the teacher acting as the focal point, imparting knowledge and directing students towards avenues of further research. Today, that method is widely recognized to be limited and whilst some learners still learn adequately using this model, there is a broad acceptance of the need for more dynamic, interactive and collaborative models of learning that truly engage students and that create the opportunity for exploration, collaboration and problem solving. Nowhere, is this more needed than in the field of STEM teaching.

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1 Science, technology, engineering, and mathematics: [https://en.wikipedia.org/wiki/Science,_technology,_engineering,_and_mathematics](https://en.wikipedia.org/wiki/Science,_technology,_engineering,_and_mathematics)
The rise of technology within the classroom has mirrored that of the wider ubiquity of technology that we see in every day life. PCs, laptops and tablets are now almost as commonplace within the classrooms of Europe as the calculator was a decade ago. Use of the internet as a research tool and the adoption of a range of learning applications across the curriculum are widespread. Many classrooms also have interactive whiteboards installed and schools are increasingly looking to invest in touch-screen technology (mainly tablets) in order to create the kind of mobility of use that many students now enjoy in their own homes. What is more, mobile learning, and the use of smart phones as a tool of education and training, is expanding rapidly with many new players entering the market. However, we have also seen a significant gap open up between the types of consumer technology that we are increasingly buying and using at home and the use of the same technology within a classroom or other educative setting. This is in spite of the fact that the European Commission, alongside many private companies and investors, has been funding research and development in technology-enhanced learning for many years and billions of euros have already been spent.

Initial excitement regarding the educational potential of technologies like virtual reality, augmented reality, virtual labs, game-based learning and others often fades away once projects are complete and partners are faced with the prospect of turning their innovations into educational products. However, why is this? In their book [1], Ben Fink and Robin Brown provide a number of answers to this question. Their answers range from a lack of acceptance by teachers to a failure of the technology to live up to the hype. They also talk about a fundamental issue around the perception of technology as something that will be a “replacement” for humans rather than the idea that technology actually compliments what humans do during the course of educating. The case of MOOCs² is a case in point here – initial (and justified) excitement about the potential of MOOCs to change the way we learn has dissipated somewhat in the face of evidence that a huge percentage of those who have so far started a MOOC have not finished it or find that their ‘qualification’ is no recognized. At the heart of the challenge is the idea that, on the one side, you have the technologist who will say how transformative their technology will be and, on the other side, the educator who will shrug their shoulders and simply say “prove it”.

In the sections below, we explain the ambitions of the NEWTON Project and then go on to explore our proposal for a new model of impact evaluation that will help us, and others developing educational technology, to “prove it”. This is partly about researchers and developers living in the real world and facing the challenge of building products not only for the pilot study but also for the market that is highly demanding and discerning.

3 THE AMBITIONS OF NEWTON PROJECT

NEWTON³ Project is a large-scale initiative funded by European Commission in the H2020 program aiming at developing, integrating and disseminating innovative technology enhanced learning (TEL) methods and tools. Main objectives are creating new or interconnect existing state-of-the-art teaching labs and building a pan-European learning network platform that supports fast dissemination of learning content to a wide audience in a ubiquitous manner, by focusing on employing novel technologies in order to increase learner quality of experience, improve learning process and increase learning outcome. Figure 1 summarizes the main ambitions of the NEWTON Project.

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² Massive Open Online Courses: https://en.wikipedia.org/wiki/Massive_open_online_course
³ Networked Labs for Training in Sciences and Technologies: http://www.newtonproject.eu/
About impact evaluation of Project results in the *learning and teaching* domain, NEWTON envisages some activities to address the definition of a methodological framework and evaluate the improvement of learning experience, skills and teaching work for STEM subjects. Different aspects may be considered for designing this framework like the point of view of users with disabilities, user (learner and teacher) satisfaction, engagement and usability, with the final objective of applying NEWTON learning platform in different large-scale European pilots. Finally, one challenge of the Project is testing and proving the validity of a new integrated learning/teaching approach by using different technologies and concepts available in a European context.

### 3.1 Large-scale Pilots in NEWTON

As an Innovation Action, NEWTON Project aims at validating the platform impact (as well as its underlying technologies and methodologies) in terms of effectiveness and enhancement of learning and teaching processes, by enabling some large scale pilots involving secondary, vocational schools and Universities from different European countries.

Each pilot is organized as real “sub-projects” by engaging different project partners and “end-user” Institutions, and it is characterized by specific scenarios and experimentations interconnected each other, in a sort of a learning experiential pathway. In fact, the basic idea consists of designing a complete learning experience by accessing to STEM subjects scenarios and/or experimentations in a smart-interconnected manner and enabling gamified and virtual reality-based interactions in order to increase learners’ motivations and engagement.

For example, the pilot designed for the secondary school in Italy consists of many stages, also by implementing gamification elements (e.g. points, badges, levels, etc.) and rules. Firstly, students can learn spatial geometry concepts, successively they can design some geometric shape using appropriate tools and, lastly, they can get the production of the same designed shape by accessing to Fabrication Lab connected with NEWTON platform. The final stage regards the assessment process and impact evaluation carried on by NEWTON methodologies mixing the usual assessment process by teachers and feedback from learners.

### 4 A NEW EVALUATION MODEL

The diagram below shows the main aspects of the new evaluation model that we are proposing. We will explain the main elements of this model over the following pages.
Figure 2 shows an overview schema of the overall model designed for evaluating the innovative educational learning process realized through NEWTON Learning Platform. Students realize their own learning processes by using innovative technologies offered by NEWTON platform. Information generated during the educational experience is collected and used by appropriate ICT tools and methods for making learning analytics in order to support evaluation of the experience. Main processes of the evaluation are: (i) knowledge and skills acquisition; (ii) student engagement and motivation; (iii) impact analysis of the technology on teachers. The following sub-sections describe details about each element of the model.

4.1 The focus for evaluation

In describing the main elements of our model, we will first look at perhaps the most important aspect of any evaluation model: what is it that we are looking to evaluate. In too many cases, not all aspects that are relevant to a real-world learning environment are taken account of in the testing and validation. The sections below explain each of the individual aspects that we are seeking to understand:

4.1.1 Knowledge and skills acquisition

Perhaps the key area for many educators when they ask the “prove it” question is around the acquisition of knowledge or skills. Put another way, the question is whether the specific technology helps the educator to do the following:

- **Achievement of learning objectives**: does the technology actually help the learner to gain a greater understanding of a topic, theme or idea? Or, does the technology help in developing a new skill or competency?

- **Progress towards specific learning targets**: does the technology play a role in moving the learner towards a particular goal? Does it do this in a way that other approaches have failed to do?

- **Proving learning retention**: is there evidence that the learning that is achieved through the implementation of the technology is actually retained by the learner and that they are able to apply this learning to other contexts?

In proving the impact on knowledge and skills acquisition, it is vital that there is some form of control group. This means that a cohort of learners will need to be undertaking the same educational
programme as the pilot group but without the aid of the educational technology. This can be more challenging than it sounds when working with schools as many may be resistant to the idea of a control group (as this will be a group that is potentially getting less educational help than the pilot group). However, educational attainment measured in this way can provide powerful evidence. As an alternative, it is possible to use existing progress data to compare with own pilot group but the profile of the cohort must be similar and the testing needs to be based on measurable progress from one point to another.

In addition, there is another critical factor that will play into the success (or otherwise) of the pilot group: the experience and ability of the teacher. Furthermore, the willingness of the teachers to embrace the technology and their own skill with technology, will impact on the efficacy of the tested solution. These factors will need to be assessed alongside educational progress and then the results weighted accordingly.

4.1.2 Student engagement and motivation

Alongside knowledge and skills acquisition, we also propose the importance of evaluating student engagement and student motivation. These factors are recognised as being critical to the success of any educational intervention and so should be measured as contributory factors in the impact analysis. When we think about these factors, we are looking specifically at the following:

- **Enjoyment of the learning experience**: the extent to which learners embraced the technology were captivated by it and wanted to return to it repeatedly. Bear in mind enjoyment will vary from learner to learner so the impact on outcomes must be weighted accordingly.

- **Attractiveness towards the technology**: it will be important to understand, as part of the initial pilot group analysis, what the perception of technology is before the trial begins. We can make the mistake of assuming that all learners (particularly young learners) are very enthusiastic about technology whereas this is not always the case.

- **Level of engagement in learning**: there are a number of ways to measure student engagement (as distinct from student enjoyment). The degree to which students are engaged in their learning has considerable impact on the achievement of learning objectives so this is a vital area to understand in relation to any given educational technology.

- **Enjoyment and enjoyment does not always mean learning**: we will also be careful not to make judgments about impact based only on enjoyment or engagement. We know that students can be very engaged in an experience and really enjoy it, but that this on its own does not translate into learning. The example would be the playing of console games, most of which have no explicit or implicit learning objectives but certainly inspire engagement and enjoyment amongst those that play them.

Once again, it will be important here to make a comparison with other methods of teaching and learning in terms of the level and degree to which students are engaged and motivated. To do this, we will need to track student engagement and motivation prior to the introduction of the technology and then observe and measure the degree to which that engagement and motivation has increased as a result of the technology. We will also have to take account of other factors affecting motivation and engagement (like the subject matter, the skill of the teacher, the importance of the course of study to grades/exams etc.).

4.1.3 Impact on teachers

The final area of focus for our model is often neglected in other similar approaches. It looks at the impact on teachers. Teachers are the gatekeepers of the classroom and are the ultimate arbiters of which educational interventions will be used and will work best. If they are not convinced and on board, then the technology will not find a home. We will be looking specifically at the following areas in relation to teacher impact and acceptance:

- **Usability within the classroom**: this will focus on looking at the ease of use of the given technology and will consider issues of classroom management, application of the technology within specific timescales and so on.

- **Practicality within the school**: we will also consider the way in which the technology is accessible and usable within the context of the wider school facility. This will partly be about
allocation of school resources (including host devices like PCs and tablets) and any other practical aspects that may affect the use of the technology.

- **Connection to pedagogy**: it is vital that any new technology has a clear purpose within the context of a recognized pedagogy. Teachers will want to know and understand how the technology fits with their own approaches to learning and how the technology may integrate with existing pedagogies (or, indeed, whether they will need to think about new approaches).

- **Requirements for training**: a very simple question that is often overlooked is that of the requirement for the teacher to learn new skills in order to master new technology. Having this understanding is vital as many schools, and many teachers, will take against technology that they perceive will create too much of a requirement for training.

- **Change of teacher role**: some technologies (although not all) require a significant change of role for the teacher within the context of the class as a whole. This is often a case of the teacher becoming less didactic and assuming more of a facilitator/guide role. Different teachers react differently to this but it is an area that needs intelligent analysis.

- **Value and accessibility of data**: teachers are increasingly required to produce data and reports regarding the progress and attainments of their students. One of the benefits to using new technologies within the classroom is that these technologies typically generate significant amounts of data. Having an understanding of what this data is and how to use it can be a key driver for the uptake of these technologies.

- **Response of school management team**: teachers do not operate in isolation. Important decisions about teaching practices and methods are often taken in partnership with the management team within the institution. As such, the response of the teacher sits within a more strategic context, that being the response of the management team. This response may be framed in more economic terms (i.e. cost can be an issue) or it may simply be that management teams are more risk averse and are therefore reticent to invest in new technologies. Again, our model will look at this as a contributory factor in the uptake of new technologies.

There is often a perceived challenge around innovating within the classroom because some teachers are keen to do this but see opposition from school management, from parents or, in some cases, from students. The barriers that teachers face in introducing new initiatives, including new technologies, are wide and varied (as we explain above). For this reason, we have to build robust mechanisms in order to understand how teachers are impacted by our technology and be aware that impact will be both positive and negative. If we can understand this impact, and respond to it in a positive way, we have the greatest chance of seeing our new educational technologies adopted in the classroom.

### 4.2 Potential methodologies and technologies

By collecting data from students’ learning experiences, a set of information, generally heterogeneous, is available to be analysed in order to address an impact evaluation of novel technologies used in the learning and teaching process. To conduct this analysis it is fundamental the adoption of appropriate methodologies, mostly of them based on statistics techniques that allow a knowledge discovery and to evaluate the obtained results. As the information of interest is distributed on multiple dimensions, for instance kind of users, time horizon, contents and resources, motivation/engagement level and so on, the main idea is to build a multidimensional cube containing all the data and use the Data Mining approach to discover new knowledge and relationship to address/evaluate the expected impact. Then, the complete procedure consists of significantly designing this cube, and applying a set of analysis algorithms such as clustering, classification, etc.

#### 4.2.1 Educational Data Mining

Educational Data Mining (EDM) [2] is an emerging discipline which aim is the application of statistics, machine learning and data mining for analysing information coming from educational settings in order to develop/improve techniques for exploring this data and better understand the students’ trends/behaviours during their learning experience.

With the increasing use of new digital tools like learning management system, games, virtual worlds, augmented reality, simulations, MOOCs, etc., specialists and researchers need to collect a lot of data from different sources that can be aggregate over a large set of students. This information contains many variables that have to be analysed by data mining algorithms in order to discover new patterns about how students learn and also to predict what could be the future students’ learning behavior. An
other very important goal of EDM is the study of the effects of different kinds of pedagogical support provided by software-based learning approach and their consequential impact on a large-scale use.

The techniques in EDM belong to the following categories:

- **Prediction**: allows developing a model that can infer a predicted variable (specific aspect of the data) by combination of predictor variables.
- **Clustering**: data can be grouped together into a set of clusters each of which has common aspects and similar attitudes.
- **Relationship mining**: it could find out which variables are most strongly associated with other ones, or discover if some relationship between these variables exists.
- **Process mining**: it is used for extracting data from event logs in an information system to form a clear presentation in the overall activities. There are three different subfields of process mining: model discovery, model extension and conformance checking. Process mining is reported able to reflect students’ behaviour in the sequence of course, grade, etc.
- **Text mining**: it can be used for deriving information with high accuracy from textual data and resources. The main contents of the text mining are text categorization, text clustering, concept/entity extraction, sentiment analysis and document summarization, etc. Text mining is applied to analyse contents from forums, chats, Webpage or text resources, etc.
- **Discovery with models**: by using one of the previous techniques (i.e. prediction or clustering or something similar), a model of a phenomenon is developed and this one is used in another analysis.
- **Distillation of data for human judgement**: it consists of two key purposes: (i) identification, where data is distilled in order to be displayed in ways enabling the identification of well-known pattern that are nonetheless difficult to formally express; (ii) classification, data sub-sets are displayed in visual or text mode and labelled with human coders in order to be used to develop a prediction model.

4.2.2 **Likert scale**

In educational context [3], Likert scale [4] is commonly used to measure different variables depending on the definition of reference survey, by identifying their relationship in order to improve the learning and teaching process.

This technique concerns the generation of survey to submit to users consisting of a set of items (these are real statements rather than questions) semantically connected with the aspects to be investigated. Each user can be agree or disagree by selecting one of the five (or, in some cases, seven) agreement degrees. The related answers represent what is the attitude or the behaviour of that user respect to a specific object or topic (identified by the same corresponding item).

Generally, the main difficult issues are the analysis of items useful to define the concept of attitude/behaviour towards an object, the validation of scale, i.e. how that behaviour is close to the reality, and the control of the distortions generated by the scale itself, and some statistics techniques are used to correctly address the issues and prevent them.

4.2.3 **Qualitative evaluation methods**

In the education context, assessments are standardized and normalized in an effort to give accurate and reliable results to students and to teachers regarding the achievement of educational objectives. These assessments are largely designed as “quantitative measures” of student understanding. While there is a lot of work being done to develop instruments and tools for assessing understanding and knowledge acquisition, few quantitative measures provide an in-depth picture of student thinking, student motivation or the reaction to a student’s educational experience. Adopting a qualitative approach that emphasizes exploring student thinking, student feeling and the student experience through observation, discussion and son on - rather than only relying on data – can be highly complimentary in understanding the impact of a learning intervention. The principal qualitative evaluation methods (QEM) we propose are as follows:

- **Focus groups (students/teachers)**: focus groups can be highly effective in creating a forum for discussion and feedback during and after an education intervention. The main goal of the focus group is to promote self-disclosure among students or teachers and to create a dialogue
between the group and the facilitator. Because a group, rather than an individual, is asked to respond to questions, this dialogue tends to take on a life of its own. Participants answer to the comments of others and this can add a richness to the dialogue that could not be achieved through a one-on-one interview [5][7]. Focus groups also allow the facilitator to guide or further explore topics that are of interest, ensuring that all avenues are covered. Focus groups can be particularly effective with groups of young learners who may respond less positively to other forms of assessment and often feel more comfortable within a group discussion.

- **Observational assessment by teachers**: observation of students by a teacher in order to gather information for recording and reporting student progress and student experience can be highly effective and valuable in understanding the impact of educational interventions. Teacher observation can be characterised as two types: *incidental* and *planned*. *Incidental* observation occurs during the on-going activities of teaching and learning and the interactions between teacher and students. Unplanned opportunities emerge in the context of classroom activities, where the teacher observes various aspects of individual or group student learning. *Planned* observation involves deliberate planning of an opportunity for the teacher to observe specific learning outcomes. This planned opportunity may occur in the context of regular classroom activities or may occur through the setting of an assessment task [6][7].

- **Independent observational assessment**: one of the benefits of observational assessment by teachers is that the teacher will typically know the students well and will therefore have a reference point on which to judge the impact of a particular learning intervention. However, there is another view – that the observation should be independent of the teacher in that an independent observer will bring an unbiased view to the observation. The basis for the observation will be the same – a mix of incidental and planned – but our model proposes that both teacher observation and independent observation are undertaken and then the results of this can be compared and contrasted for a fuller picture.

- **One-to-one interviews**: interviews with single learners – and with teachers – will provide valuable information about the learner experience, learner motivation and learner progress. A student interview requires extensive preparation. In order to facilitate it, a five-step approach can be followed [8].
  - **Step one - Gather Data**: once teachers have identified a student, it is necessary to gather data. This data may include assessments, report cards, and information obtained from conversations with teachers.
  - **Step two - Develop Preliminary Theories for Student Performance**: student interviews that are open-ended are interesting and informative but it is important to focus on specific concepts and/or aspects of learning. Development of preliminary theories regarding learning experiences or outcomes starting from collected data can help to address this aspect.
  - **Step three - Collect and/or Create Themes and Questions to Use in the Student Interview**: collection of necessary themes that will drive the interview is an important aspect to be considered when preparing for a student interview. The aspects the interviewer chooses need to examine the preliminary theories developed in Step two, focus on a particular topic and be complex enough to allow for rich conversation with the interviewee.
  - **Step four - Secure the Interview Logistics**: it is important to arrange the logistics, from requesting permissions (parental consent) to attaining the appropriate material to establishment where the interview will take place.
  - **Step five - Conduct the Interview**: the interview should begin by building trust with the student, generally by selecting a familiar setting/context in which to conduct the interview. For example, talk with the student about his/her interests, educational experiences, etc. In addition, the interviewer should emphasize that he/she is not very concerned with the correctness of student’s answers, but is much more interested in the student’s thinking.

The interviewing of teachers can take a more unstructured approach although standardised questions are useful in ensuring that information gained is consistent across different interviews.

- **Standardised motivational/engagement tests**: there are a number of existing tools and metrics that can be used to measure student engagement and student motivation. In our model, we suggest adopting one or a number of these tools depending on the specific learning context, age of the learners and so on. Further work will be done to review these tools but, at present,
we are interested in exploring the ten 'Engagement Indicators' developed by the National Survey of Student Engagement in the USA\textsuperscript{4}.

5 CONCLUSIONS

Once we have completed our pilots we will have a great deal of data to draw on and will publish this alongside an analysis of the effectiveness of our model. We will use the Newton Project as a kind of 'living laboratory' in order to validate the different aspects of our model and then to explore the nature and power of the story that emerges from our experiences. The true test of whether our model is effective will be the degree to which our technology, if deemed effective by our evaluation, is trusted by educators as being such.

REFERENCES


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