Using Educational Robotics Research to Transform the Classroom

Establishing a Robotics Community of Evidenced-based Practice using MESH Guides and the TACTICS Framework

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***Abstract*— Trends in the USA and UK insist that classroom interventions are supported by evidence of their efficacy. The body of evidence supporting the value of educational robots is growing. However, a perennial problem remains, how can such evidence impact everyday teaching and the use of educational robots in the classroom? MESHGuides are created by an international network of educators who are mapping the research base underpinning educational practice and making it readily available to teachers anywhere in the world. The TACTICS Framework sets a standard for how research information should be integrated into evidenced-based activities and how these activities can be used to inform research. This paper introduces these ideas and shows how they have been applied to the Turtle type educational robot, Roamer.**

Keywords—MESHGuides, TACTICS, Roamer, Educational Robotics, Turtle, Teaching with Robots, TWR, Evidenced Based Education, SBR

I. INTRODUCTION

Educational Robots are tools with the potential to help teachers deliver the curriculum in most subjects and across most of pre-K-12 education. In the UK the use of robots (programmable toys) has been part of the National Curriculum since 1989 [1]. However, despite this Valiant Technology's commercial experience (confirmed with a number of other vendors) shows that few teachers use educational robots to their full potential. To get the most out of educational robots requires a high level of teaching skills and expertise with the technology. To transform this situation requires both and in most cases this requires a systemic change. The Educational Robotic Application (ERA) Practical Principle identifies five elements necessary to achieve such change: Vision, teacher buy-in, training, resources and an action plan [2].

This paper reports on work aimed at supporting this type of transformation on an international scale using Web 2.0 technologies. It builds on previous research relating to Turtle Type robots in general and especially with the Roamer. It reaffirms that appropriate training and the availability of high quality activities that meet the requirements of the ERA Principles are essential for the widespread adoption of educational robots. The ERA Curriculum and Assessment Principle is particularly important. This states "*Educational Robots can facilitate teaching, learning and assessment in traditional curriculum areas by supporting good teaching practice*". Catlin [3] proposed that the approach described as Assessment for Learning (AfL) based on the work of Black and William [4] captured "good teaching practice" in a series of strategies that bear a natural empathy with educational robotics.

There is another factor, which has increasing importance: the need for educational interventions to be evidence based. Catlin and Blamires discuss the problems associated with this in e-Robot [5]. They proposed that it was important the research informed practice and practice informed research. Moreover, they proposed that such research needed to be ongoing over decades, not years, and the only practical way of doing this was via the internet. Valiant has been developing such systems over the last few years and now has an integrated Activity Library [6] and Training site [7][1]. This provides teachers with "just-in-time" and "on-the-job" training embedded in each activity. There still remains a number of challenges: how does such a system collect data about the effectiveness of each activity, how can such information be coordinated with other research and how can it be made accessible to classroom teachers? The recent launch of the MESHGuide[2] initiative provides an answer to these questions. This is supplemented by the TACTICS framework which provides an organising structure for ensuring that research is built into interventions and that the outcomes of interventions inform research.

This paper first reviews the current demand for evidenced based interventions. It will then discuss how this impacts educational robotics, before introducing TACTICS[3] and MESHGuides. It then illustrates how this is being applied to Roamer before concluding with an outline of work still to be done.

II. SCIENTIFIC BASED EDUCATIONAL RESEARCH

In 2001 the No Child Left Behind (NCLB) Act was launched in the USA. One aspect of this programme was the insistence that Federal funding could only be spent on interventions that were validated by Scientifically Based Research (SBR) [8]. The US authorities presented the medical research model as something education should emulate. A similar sentiment, but without the financial cudgel, was promoted in England by Michael Gove, the erstwhile Secretary

[1] Apply for a Guest Login to access these sites.
[2] **M**apping **E**ducational **S**pecialist know How
[3] **T**argeting relevant outcomes, **A**nalyzing best practice, **C**larifying environmental considerations, **T**ranslating best practice, **Interpreting** resulting outcomes, **C**ommenting on transformations, and **S**electing next steps.

of State for Education when he urged Ben Goldacre, the author of Bad Science [9], to write and champion a similar concept [10]. These sources promote a hierarchy of research methods which made Random Control Trials (RCT) the gold standard. Some of the rhetoric supporting this position has been dismissive of the qualitative paradigms like ethnomethodology which when used with educational robots has proven to be a useful tool in revealing the thinking process of students [11]. The debate is not new. Cohen and Mannion review the theoretical aspects of both sides [12] and Darling describes the effect of a previous positivist attempts at eliminating qualitative research [13].

It is easy to agree that evidence based practice can only be a good thing. The issue is what constitutes good evidence? Catlin and Blamires [5] propose the use of the internet as a means of gathering and collating teachers experiences. Hans Rosling, who like Ben Goldacre is an epidemiologist, proposes that this is a new way to gather "valid evidence" [14].

The US Government supported their policy by setting up the What Works Clearing House [15]. The aim of this was to collect and collate evidence to inform teaching practice. So far 10,500 study reviews are available. Yet this has resulted in a moderate 18 practice guides containing recommendations about how teachers can use this research to improve their teaching practice. A similar "what works clearing house" has been established in the UK with the Sutton Trust. For educational robots to gain credibility in this climate, the production of suitable guides is essential.

III. Issues with Educational Robots

It is difficult to "prove educational robots work" because the robot is a tool. The challenge is akin to proving that a pencil works! Clearly it depends on what you do with it and your skill at using the technology. The nature of the activities vary; for example the Number Grab Activity [16] is radically different from the Roamer Spacecraft Rescue project. The latter was recently subject of a doctoral dissertation [17]. It is a reasonable, but impractical argument that almost every activity deserves similar doctoral scrutiny. This problem was addressed with the publication of the Principles of Educational Robotic Applications (ERA) [2]. This summarised 30 years of empirical experience of educational robots into ten basic tenets that could be used for the purpose of meta-analysis; review of the value of educational robots and the design of new robots and activities.

At this stage ERA is a hypothesis and the e-Robot project was proposed as a strategy for developing and validating the theory. e-Robot criticises the restrictive approach of NCLB Research and states a more eclectic view on what constitutes valid evidence [5]. Thorndike pioneered the application of SBR in education. He was very much the scientist dispensing wisdom to classroom drudges [18]. Teachers were there to apply other people's thinking. Under NCLB a teacher's practical experience is disparaged as anecdotal. Yet the reality is most teachers rely on their experience, which is often by its nature expressed in anecdotal form. One argument against this form of evidence is that "Sometimes they [anecdotes] are very representative, sometimes they're not. The problem is we don't know when." [8]. The e-Robot project proposes that we can use the web to find out whether such evidence is representative of a wider view.

The e-Robot perspective is that all data and various valid research techniques can contribute to the evidential base. It suggests that there is a constant interplay where research informs practice and practice informs research. Interplay also works between activities and ERA. The data collected from activities can assist the verification of ERA and ERA can help the formulation of the activities. The MESHGuides offer a way of collating and presenting the various forms of evidence in a way that is accessible to teachers. They represent an educational version of the NICE Guidelines used by the medical profession in England and Wales to resolve a similar problem is disseminating research information to medical practitioners [19].

IV. Teacher Skills

The US Department of Education classifies teachers in accordance with their experience [20]. For our purpose we use Resident Teacher (someone just out of teacher training) and Master Teacher (an exemplary educator who models effective teaching practices and acts as a resource for the whole school). Not everyone who uses Roamer in a teaching situation is a trained teacher. The other dimension of the skill is the ability of the teacher to use the technology effectively (see Fig 1).

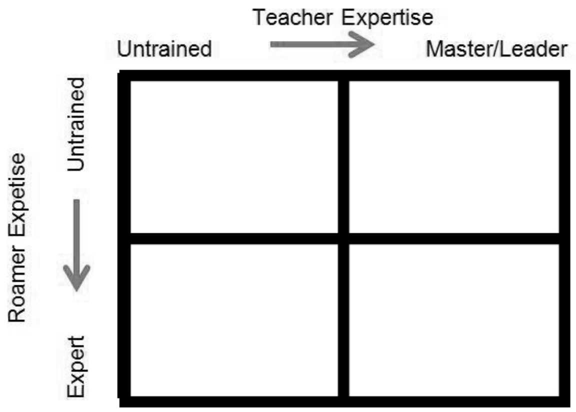

Fig 1 Teacher Skill Matrix

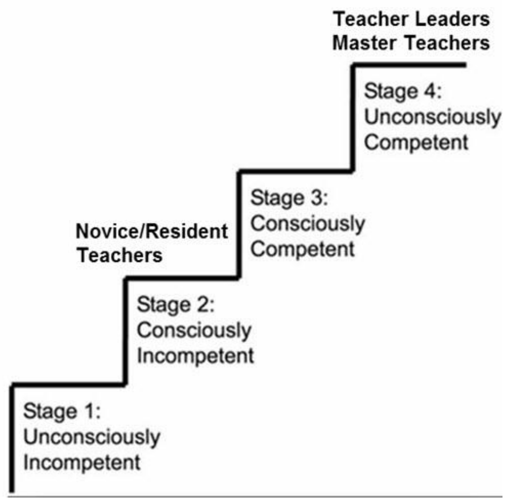

Fig 2 Gordon's Ladder of Competence

The potential of a successful outcome depends on the teacher's position in this skill matrix. To meet the requirements of the ERA Practical Principle, any activity needs to take into account potential short comings in these skills, which essentially means activities must also incorporate appropriate training. Created by Noel Burch, the Gordon's Skill Ladder (Fig 2) offers another way of viewing teacher's competence [21]. While training built into the activity can move people from Step 1 to Step 2, only practice and continual training can help people make the transition from 2 to 3 to 4. TACTICS [22] provides a framework that sets a standard for activities. The standard aims to support the transfer of expertise from master teachers and the process of gathering evidence of practice.

V. THE TACTICS FRAMEWORK

The TACTICS Framework shown in Table I provides teachers with the seven elements necessary for creating an effective activity.

TABLE I. THE TACTICS FRAMEWORK

TACTICS Element	Definition
Targeting relevant outcomes	Links to national or state curriculum standards and the learning intentions identified by the student
Analysing best practice	What is the best evidentially based approach (AfL, MESHGuides, ERA Principles, Practice Guides, etc.)
Clarifying environmental considerations	What are the pertinent characteristics of the learning environment engaged in the activity.
Translating best practice	The contextualization of a known best practice , c.f. a research informed lesson and assessment plan.
Interpreting resulting outcomes	Measuring and recording the outcomes with qualitative comments on what happened in the activity.
Commenting on transformations	A brief comment on the overall impact of the activity on the teacher and learner.
Selecting next steps	Decision on what to do to further improve learning outcomes based on the results.

The design of the TACTICS process reflects a consideration of translational research [23] a methodology, which has its critics [24], but is establishing a presence in the medical field [25] as an approach to rapidly translate research findings into practical setting like classrooms.

Valiant has invested a significant amount of research into the development of a Roamer activity structure, independent of TACTICS. There was around a 90% correlation between the two approaches. The TACTICS framework was used to modify the Roamer Activity Structure and was particularly helpful in regard to the development of the Lesson Evaluation feature which meets the e-Robot data gathering requirements. Establishing a standard approach towards gathering and disseminating research, and incorporating it into the development and presentation of activities has the benefit of making it easier for teachers to quickly comprehend and implement activities (The ERA Practical Principle). The TACTICS Framework offers a structure for this process.

VI. MESHGUIDES

MESH is a key global initiative to understanding how 21st-century technologies can be harnessed to improve the quality, relevance and timeliness of educational research [26]. MESH (Mapping Educational Specialist know How) is a global knowledge management strategy. It produces a MESHGuide: an online resource (equivalent to the US Practice Guides) which links to evidence, collates, cross references and summarises it. It is accessed and supported by an online network, which links practitioners and researchers enabling them to form working groups, or communities of practice.

The MESHGuides initiative was developed by the Education Futures Collaboration (EFC), which is an educational charity in which the founder members were inspired by a variety of approaches in the field of medicine and other public sector organisations with respect to knowledge management strategies. The governance of the MESHGuides initiative is managed by the Education Futures Collaboration charity.

Given that published educational research is rarely focused on the knowledge teachers need to improve their professional practice, MESHGuides seek to change this so practice and theory are 'mesh-ed' together to provide research-based advice for teachers. MESH is a worldwide network of educators freely sharing, and building professional knowledge. MESHGuides synthesise and make accessible the evidence base for educational practice from across the world so that teachers at all levels can keep up to date easily. For researchers, good practice in research writing includes communicating findings to users and this includes teacher practitioners.

To achieve this vision, the MESHGuides website enables research to be accessible at the touch of a button, as any internet enabled device will be able to access the guides or knowledge maps of educational research. This means that the widespread uptake of mobile technologies will enable practitioners as well as academic researchers to connect to a large body of knowledge, in the form of previously published research, which helps to ensure evidence- based professional practice.

The long term aim is to have a completed A to Z index, which covers all curriculum subjects and areas of educational interest, alongside key concepts and generic issues, such as assessment, pedagogy, SEN, threshold concepts, barriers to learning and so on, so that the index is searchable by key term. The use of an A-Z index is how the maps of medicine are organised for the medical profession to access research evidence. The MESHGuides are overseen by editorial boards of academics and teacher practitioners who review the guides once they have been written and submitted. The guides are then subject to peer review and an editorial process, which provides a quality assurance process that is the same as print publishing of educational research. This process allows experts to contribute to a range of guides within their expertise and to interact and network with colleagues in the same field. Thus collaboration is between academic researchers and teacher practitioners, who have a dynamic expertise between them of theory and practice. This frees research from the circle, in which academic research resides behind the firewall of academic journals (to be read almost solely by other academics), preventing teachers having their practice informed by research, unless they can access the research databases behind University library paywalls. Free at point of access, MESHGuides provide an overview of educational research on a given topic. It references previous published research, and enables the profession to utilise the evidence to inform both future practice and research. While the Guides summarise known research, they also make the raw data and references accessible to other researchers, which enables individual reviewers to make up their own mind about the quality of the evidence.

VII. MESHGuide For Roamer

The MESHGuide resolve the issues identified in the e-Robot paper. For the reasons cited above it is an ideal tool for handling evidence on Roamer's effectiveness and the validity of the ERA Principles. The following is structure of the MESHGuide entitled: Educational robots: why use a Roamer robot in the classroom [27]? The rest of this paper will review this structure and use the Roamer Activity Number Grab (Whole Numbers) to illustrate various issues [28].

A key aim of the e-Robot research programme is the verification/development of the ERA Principles. These effectively provide a summary of evidence of why educational robots are effective educational tools. The MESHGuide is focused on the definition of these principles, linked to the currently available evidence. It includes a summary of the status of the evidence supporting the principle and what work needs to be done. The rest of the guide is set up to gather evidence from three different sources: first substantial data available from Logo and Turtle research, relevant data from various scientific fields (developmental psychology, AI, science of learning, etc.) and the information gathered from activities in the Roamer Activity Library. These activities derive from various sources: Valiant's archives, teacher submissions and Valiant's new activity development efforts. TACTICS compliance provides a natural two-way information flow between activity and research.

Fig 3 shows the MESHGuide Matrix. The amount of evidence will be substantial so it requires categorization. It is organised according to its research format (peer reviewed journals, dissertations, action research, etc.). It was considered that this section should be organised around topics. Teachers will want to find evidence for topics. However, the topic range is too large and subject to variations like spelling differences. So the plan is to use tags to identify topics and facilitate a tag search feature. The context will derive from data collected from the schools using the activities. Once sufficient data has been collected it can be summarised into useful categories. The activities are linked to the evidence and cross referenced to subjects, age groups and cultural situation. The design of the activities provide evidence for the ERA Principles: Sustainable Learning, Curriculum and Assessment, and Pedagogical. All of this information is provided within the structure of a Roamer activity.

However, the key element is how successful was the activity? How do we measure this? The normal way is to test against the Lesson Objectives (normally aligned to curriculum). This is unsatisfactory and misleading. Children's understanding of concepts emerges gradually as they experience a variety of interventions. The situation is analogous to a boxer who knocks out his opponent in round 11. Could the "knockout blow" win the fight without the contribution of the other punches delivered in the previous ten rounds? To resolve this problem Roamer activities include a Lesson Evaluation survey which measures performance against success criteria.

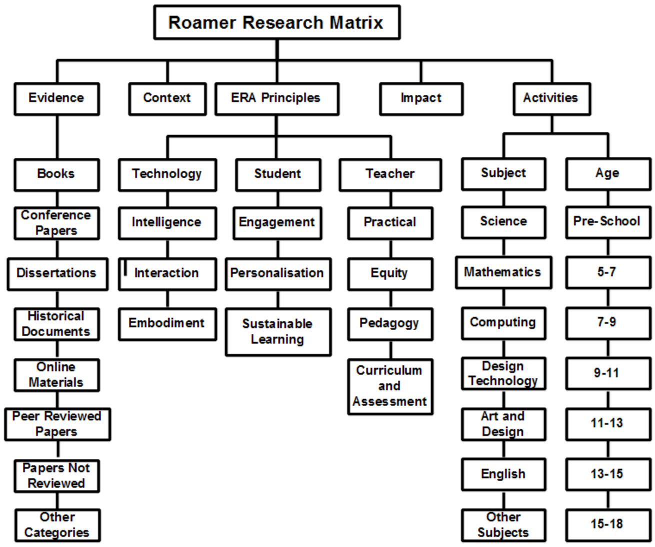

Figure3 Roamer MESHGuide Matrix

Assessment for Learning (AfL) techniques are embedded in Roamer activities. Two of these are learning intentions and success criteria. The learning intention is not the same as Lesson Objectives. It is related, but it is what the students thinks they are learning. It is something set up by the teacher as she engages students in the activity. Part of that set up process is helping the student to understand when they are successful. This is part of the self and peer assessment methods of AfL. It has been shown that students are remarkably honest in their appraisals [25]. This opinion is moderated by teacher's observations of the lesson.

VIII. Conclusions

The MESHGuides and TACTICS Framework provide useful tools for resolving problems identified in the e-Robot paper. They have been used to modify the organisation of the Roamer Activity library and set up a situation where continuous gathering of information from practising teachers on the effectiveness of educational robots, expressed by the ERA Principles, is possible. Some research is necessary, in particular to validate the notion of using success criteria and no doubt various modifications to the overall structure will take place over time. The main efforts in the immediate future will and existing research to the guide and proactively pursue the collection classroom activity-based data.

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REFERENCES

[1] Mathematics National Curriculum, England, Department of Education, 1988

[2] D. Catlin, and M. Blamires, "The principles of Educational Robotics Applications (ERA): A framework for understanding and developing educational robots and their activities," *Constructionism 2010.* Paris: Proceedings of Constructionism 2010.

[3] D. Catlin, "Maximising the effectiveness of educational robotics through the use of assessment for learning methodolgies," *3rd International Conference on Teaching Robotics, Teaching with Robotics.* Riva La Garda, Italy. Proceedings 2012.

[4] P. Black, P. and d.Wiliam, "Inside the Black Box: Raising Standards Through Classroom," NFER Nelson. 2006.

[5] D. Catlin, and M. Blamires, "The e-Robot project: A longitudinal on-line research collaboration to investigate the ERA principles." *TRTWR 2010 Conference, part of SIMPAR 2010* . Darmstadt, Germany, 2010.

[6] Roamer Activity Library http://activities.roamer-educational-robot.com accessed 25th January 2015.

[7] Roamer Training Site http://training.roamer-educational-robot.com accessed 25th January 2015.

[8] Transcript,"The use of scientifically based research in educationl" Conference Working Group USA Department of Education, http://goo.gl/UqGw9S accessed 26th Jan 2015, 2002.

[9] B. Goldacre, "Bad science," *Harper Perennial*, London, 2009

[10] B. Goldacre, "Teachers! What would evidence based education look like," *Department of Education (England)*, http://goo.gl/VUrkUg accessed 26th Jan 2015, March 2013.

[11] R. Beghetto, "Scientifically based research". *ERIC Digest. ERIC Identifier ED474304* http://www.ericdigests.org/2003-5/based.htm accessed 26th Jan 2015, 2002

[12] L. Cohen, & L. Manion, "Research methods in education. London and New York: *Routledge*1997

[13] J. Darling, "Child-Centred Education and its critics." London: *Paul Chapman Publishing Ltd*. 1994.

[14] H. Rosling, "The joy of stats," *Wingspan Productions and broadcast by BBC*, http://www.gapminder.org/videos/the-joy-of-stats/ accessed 26th Jan 2015, 2010

[15] What Works Clearing House, Institute of Education Sciences, http://ies.ed.gov/ncee/wwc/ accessed 26th Jan 2015, 2010

[16] Example Activities http://activities.roamer-educational-robot.com/ accessed 17th April 2015

[17] S.K. Holmquist, "A multi-case study of student interactions with educational robots and impact on Science,Technology, Engineering, and Math (STEM) learning atitudes." PhD. Dissertation, *University of South Florida*, http://goo.gl/YEcmAk accessed 26th Jan 2015, 2014.

[18] E. C. Lagemann, "An elusive science: the troubling history of education research*". University Chicago Press*, Chicago and Londong, 2000.

[19] "NICE guidelines", National Clinical Guide Line Centre, http://www.ncgc.ac.uk/Guidelines/Methodology/ accessed 26 Jan 2015.

[20] U.S. Department of Education., "Section IX—Appendix: Sample Teacher Role Structure, Retrieved from The RESPECT Project: Envisioning a Teaching Profession for the 21st Century", , http://goo.gl/1kLm5g accessed 26th Jan 2015.

[21] N. Burch, "The conscious competence ladder" Gordon's International, http://goo.gl/sAhkqJ accessed 26th Ja 2015

[22] J. O'Meara, The Contribution of the TACTIC mapping framework and teacher effectiveness studios to teacher effectiveness. *Journal of Education for Teaching*, in press

[23] S. Wolf, "The Meaning of Translational Research and Why It Matters". *Journal of the American Medical Association*, 299(2):211-213, 2008

[24] F. Prinz, T. Schlange, and K. Asadullah, "Believe it or not: how much can we rely on published data on potential drug targets?" *Nature Reviews*, Volume 14, No 1 January 2015. Accessed 30th Jan 2015 http://www.nature.com/nrd/journal/v10/n9/full/nrd3439-c1.html

[25] A. Cambrosio, P. Keating, S. Mercier, G. Lewison, G. Mogoutov, A. Mogoutov, "Mapping the emergence and development of translational cancer research". *European Journal of Cancer Research, 42 (18) 3140–3148, 2006*

[26] MESH connecting educators with sources and summaries of educational research www.meshguides.org Accessed 30th Jan 2015.

[26] Web address to follow.

[27] D. Catlin, A. Coode, "Number Grab (Whole Numbers), *Valiant Technology Ltd*. Accessed 31st Jan 2015