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Brief Report

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KIKS Creativity and Technology for All

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Abstract: To help meet an educational and societal requirement for all students to enjoy, have confidence and ability in creativity and technology, the "Kids Inspiring Kids in STEAM" (KIKS) EU project adopted an intensive Hothousing process challenging students in Finland, Spain, Hungary and the United Kingdom to engage in collaborative problem solving to develop solutions to: "*How would you get your schoolmates to LOVE STEAM?*" The project provided a process and technology toolkit for students, including those with special educational needs, to achieve their solutions.

A completion rate of 90% suggested that all schools and students could cope with and enjoy the process and associated technology toolkit, which featured social media plus Micro:bit, Tracker and GeoGebra for data collection and modelling.

We have extended the toolkit with simulation software and a graphical programming environment to produce realistic animations of objects in motion. Thus students will have a creativity and technology toolkit to experience the kinds of techniques and skills used by software engineers in the video, games and special effects industries. The toolkit will be on the GeoGebra platform which, in addition to mathematics, embraces STEAM and social media.

Keywords: STEAM; Inclusion; Data Modeling; Creativity; Technology.

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1 Introduction

STEAM (Science, Technology, Engineering, Arts and Mathematics) is not new. Isaacson (2014) quotes computing pioneer Ada Lovelace's (1815-52) definition of "Poetical Science" as merging creativity and technology, and in similar vein, Steve Jobs' 2011 description of Apple as technology married with liberal arts. In addition, Isaacson identifies multi-disciplinary collaborative/team working as key to creative real-life STEAM problem solving.

Unfortunately, fewer and fewer students in schools and universities take STEAM subjects and the popularity of these subjects is also decreasing. Many European countries achieve low marks in international assessments such as PISA (OECD, 2013). Yet students' STEAM-related knowledge and skills are increasingly important for economies and to address challenges societies face in the 21st Century (e.g. Lavicza, 2010; Oldknow, 2012). In addition, PISA and EU2020 all recommend that children's education should foster enjoyment, self-belief and the stamina to address complex problems and situations in STEAM subjects (OECD, 2018).

How might this translate into young people working with STEAM? The International Erasmus+ Project KIKS (Kids Inspiring Kids in STEAM) approached this challenge by asking students in the UK, Finland, Spain and Hungary: "*How would you get your schoolmates to LOVE STEAM?*" focussing on a number of perspectives:

- Inclusion – how do we make the project accessible to both able and less able students including those with special needs?
- Process – how do we offer a process which gets the right balance of support and creativity?
- Tools – what technology tools and combination of tools can be used to support students in this process?

2 Inclusion

The KIKS objective is to get "kids" developing inspirational STEAM activities for other "kids" in Hothousing kick-off workshops, working on solutions in Local Challenges then extending as far as International Collaboration. Yet many children, and their parents and teachers, do not enjoy or have confidence in maths and STEAM: they have anxiety even math/technophobia and drop it as soon as they can (Houghton & Oldknow 2014). In math anxiety, this can extend as far as math-specific fear interfering with the brain's information-processing capacity and its ability to reason through a math problem (Young, Suu & Venon 2012).

So who better than to ask those more enthusiastic and/or able students to develop STEAM popularisation projects and deliver them to the less confident student audiences in the participating countries? Lander (2016) explores the mutual benefits of peer-to-peer teaching and suggests activities for students to learn from each other should be built into the curriculum, in-class and after school student clubs, this opportunity is offered by the KIKS project. Grabmeier (2017) describes international science collaboration growing at an astonishing rate extending to international STEM teaching in many projects, and we take advantage of this in the KIKS project.

STEAM offers educational situations where both these individual and social skills are required in creative problem solving challenges featuring a mixture of Science, Technology, Engineering, Art, Maths. This is also a requirement of PISA and International Baccalaureate (OECD, 2018): "Educational approaches should feature creative problem solving challenges including societal factors/needs". But does this apply to all types of students?

We deliberately worked with schools having students with very different abilities and individual and social needs. Some are very able and some unable to cope with mainstream schooling. All students, including those with mental and/or behavioural conditions, have educational and life challenges: individual cognitive, motivational, and emotional, as well as social interaction needs..

3 Process

The Hothousing Process (Houghton, 2005) is an intensive workshop technique with the objective to foster creative problem solving, communication and collaboration skills and build self-belief – on many projects. The KIKS version of Hothousing is a variant on a well-established business technique (Thomas, 2013) in which a facilitator initially leads, then gradually hands over control and supports competitive groups of employees and customers together to come up with their own creative business solutions.

For the KIKS student version, it started with an intensive multi-school creative activity workshop, hence the term Hothouse, followed by Local Challenges where individual schools work at their home school, then International Collaboration where schools share and develop their projects. In UK, Finland, Spain and Hungary there were a total of approximately 400 students – from five schools in four countries, each school with 20 students working in groups of four to six members.

The key to the activity is intensity, hence the Hothousing term:

- Student-led
- Working hard – under time pressure
- Active engagement – actually DOING something, undertaking a project and coming up with THEIR solutions
- Working with others – including outside experts from community and/or industry
- 100% engagement within team
- Having fun.

The process begins with a tightly structured Hothouse Multi-School Kick-Off agenda led by teachers. Control is gradually handed over to the student and followed by less structured (by the teachers) activities in which the students take control and responsibility both back in school in Local Challenges and then in International Collaboration. The specific Hothouse process in the different schools and countries were variants of the below. They were not exactly the same for pragmatic reasons, such as one project might be in-class whereas another an after-school club, and curricular objectives in which teachers might wish to use the process to address particular curricular areas.

The core Hothouse Kick-Off Agenda is as follows:

10.00–10.10 Welcome and Objectives

10.10–10.20 Challenge "How would you get your SCHOOLMATES to LOVE STEAM?"

10.20–11.20 Introduce STEAM stimuli experiences and experts e.g. business, technology, parents who are available for consultation. Good stimulation is essential to get the ball rolling. Following this, the onus is very much on the student's own initiative.

11.20–11.40 Students split into groups of five to address the challenge: 3 minutes discussion – then present first ideas for 60 seconds.

11.40–11.50 Receive constructive feedback from other teams and experts.

11.50–12.30 Group work discussion and agreement on "who does what", research, interview experts, further work with STEM stimuli, develop solution and plan, practice presentation in short timescale.

12.30–12.50 Group 60-second presentations/ demonstrations. Receive constructive feedback, discuss team working experience.
12.50–13.00 Discussion and student/teacher commitment to next steps, 60-second evaluation questionnaire, perception and suggestions.

The Local Challenge Session is more loosely structured:
- Welcome and Objectives
- Individual team project presentation update – feedback from pupils and experts.
- Teams work on their individual projects and are visited by our various experts receiving support as and when needed.
- Individual project presentation update and agreement on next steps and meeting.

The International Collaboration has little structure imposed by teachers other than on-line safety concerns and obligations. Students present their work, including project presentation and demonstration, physically and/ or virtually via Videoconferencing, WIKI and Facebook during the project. These are illustrated in subsequent sections.

4 Toolkit

Depending on teacher/student expertise, interest and curricular objectives, a range of tools were made available. Each of the tools supporting the Hothousing process is proven, widely available and free. They are not claimed to be the best tools for the job per se. For example, GeoGebra is a widely used tool of the KIKS researchers and teachers community and in addition to being the preferred choice, therefore offered more mutual support and expertise than Excel. Although the latter was used in certain projects. The BBC Micro:bit was first introduced and widely used initially in the UK and made available free for the four countries by the Micro:bit Foundation, although some activities were undertaken with the similar Arduino. Tracker is also widely used by KIKS educators even if the relative merits of the similar product VideoPhysics are strong. The power of the toolkit and associated expertise is when they are used together to promote technology and creativity.

GeoGebra is widely used mathematics software originating and centred at the University of Linz. It is a proven tool for both teacher professional development and classroom impact. For example, Escuder and Furner (2011) describe the positive impact of GeoGebra in Math Teachers' Professional Development and classroom impact included improved student engagement, attention and focus together with increased student interactions with instructors, and increased achievement in teaching geometry, transformations and trigonometry (Houghton, 2014).

The BBC Micro:bit proved a user-friendly, cheap yet powerful technology and in particular provided a bridge to other technologies. The Micro:bit projects developed by students themselves included activities such as a Kitronik Buggy, Traffic Lights control and Conservation of Energy. Further, the Micro:bit provided a common tool for International Collaboration via a WIKI, MOODLE and Facebook, and also collaborative projects such as Chain Reaction (described in section 6.1).

For Tracker, the US Open Source Physics project Compadre was funded by the National Science Foundation from 2006 to develop curriculum resources that engage students in physics, computation, and computer modeling. The Cambridge Centre for Innovation in Technological Education CCITE received an HP Catalyst STEMx Academy award in 2012 to develop a MOOC called *Analysing Sporting Performance* for video capture and analysis from movie clips of objects put in motion by the students using Tracker software for data-capture and GeoGebra for graphing and analysis (Oldknow & Houghton, 2012).

Bitty Data Logger Apps (Wooley, 2017) were developed for Android and Apple mobile devices to read and display data captured from Micro:bit sensors in real-time.

Putting the tools together, in the following example, a Micro:bit is strapped to a heavy wooden mobile (an elephant called Ellie) with elastic bands. Ellie is suspended from a door frame on a stiff metal spring. The idea is to capture y-acceleration data over Bluetooth in real-time. The Bitty data logger software will plot the graph of acceleration against time. The file can be downloaded to a laptop and opened with a spreadsheet such as MS Excel. We can transfer data from Excel to Tracker and analyse it in GeoGebra.

A video clip of the above action has been copied from a camera to the laptop, and opened in Tracker (See Figure 1).

The movement can be manually and/or automatically tracked and the data visualised. The data can then be pasted and analysed in a GeoGebra spreadsheet view (See Figure 2).

This example shows how scientific and engineering experiments can be easily measured using Micro:bit's on-board sensors, and enhanced with other devices and free software tools such as Tracker and GeoGebra to analyse and model the data mathematically.

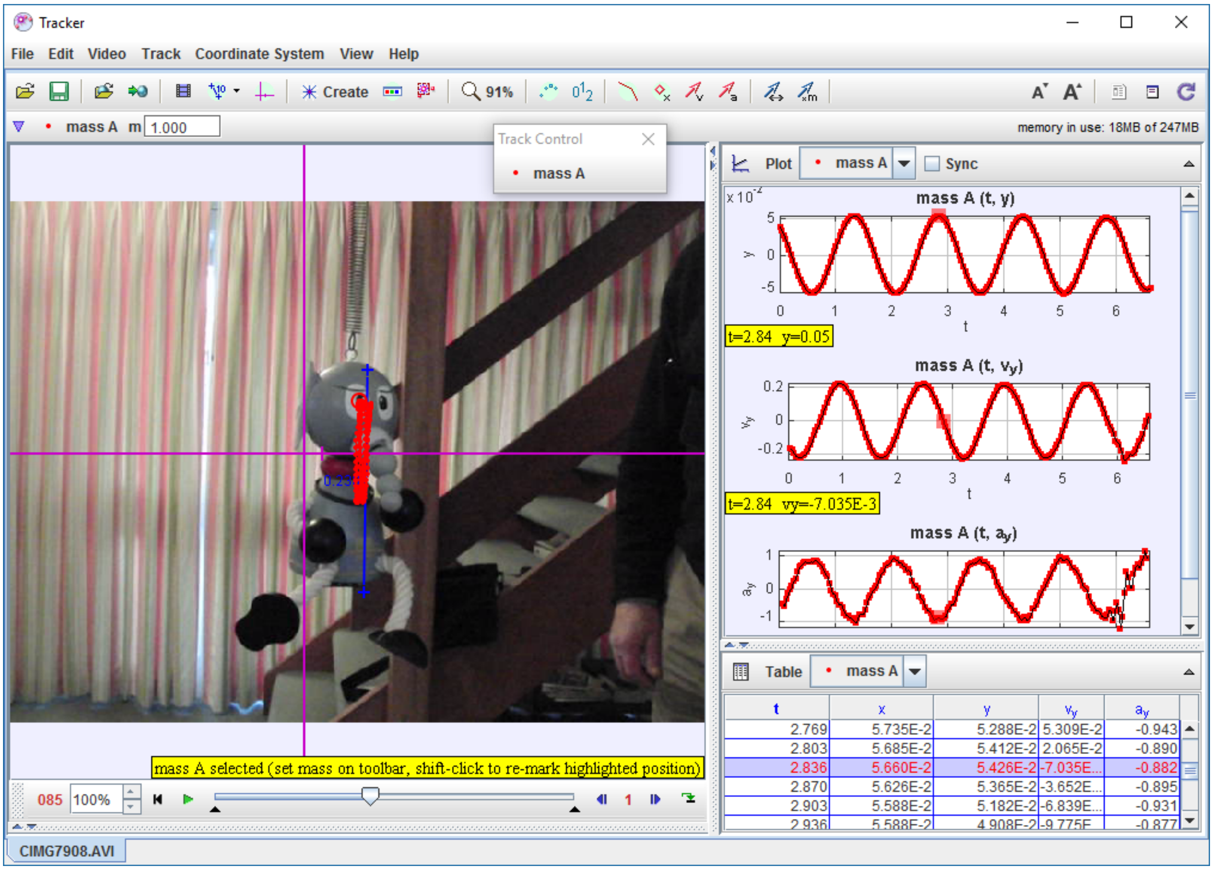

Figure 1: Capturing movement data from a video clip using Tracker.

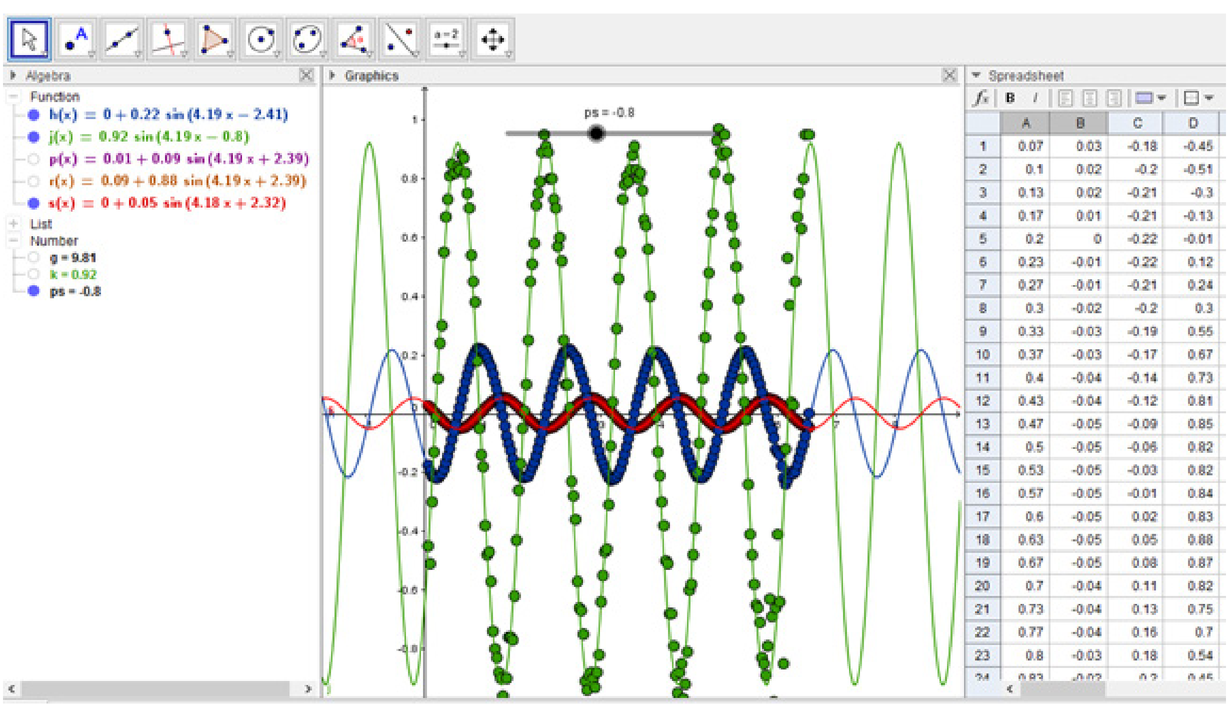

Figure 2: Analysis of Tracker Data using GeoGebra.

Figure 3: KIKS Moodle.

5 Student Projects

In the Local Challenges, a number of student projects were developed as reported by the students. They can be seen on the KIKS Moodle Guest View (See Figure 3) together with support material offered by researchers and teachers[1].

A few project examples are presented, taken directly from the students' input. The intention here is to illustrate collaboration rather than technical qualities of the projects.

5.1 Conservation of Energy

This project was undertaken by Rainham Mark Education Trust and IET (Institution of Engineering and Technology). Three sixth formers designed, prepared and delivered it. As a theme, they decided on the conservation of energy; a fascinating and relevant challenge. The team also posed a further challenge for the KIKS team: Could we use Tracker, GeoGebra, Bitty or anything else to get Micro:bits to track the balls? This meant that the team had to learn about free online software and some electronics with modern electronics – they used the BBC Micro:bit computers for control (See Figure 4)[2].

5.2 Kitronik

In this project a Kitronik buggy (electronics and mechanical assembly kit) is controlled by a Micro:bit including the use of the onboard accelerometer to change direction on impact[3]. The Year 11 Engineering Society members designed the activity to challenge their colleagues in Years 9, 10 and 12. This is a good example of using an existing STEM resource and enhancing it by adding on the Micro:bit as new technology. Adding this technology also enhances the learning outcomes for students but

1 These materials may be accessed as a guest or by registration at: https://istemplus.moodlecloud.com/course/view.php?id=3#section-17

2 Materials accessible at: https://istemplus.moodlecloud.com/course/view.php?id=3#section-9

3 Materials accessible at: https://istemplus.moodlecloud.com/course/view.php?id=3#section-12

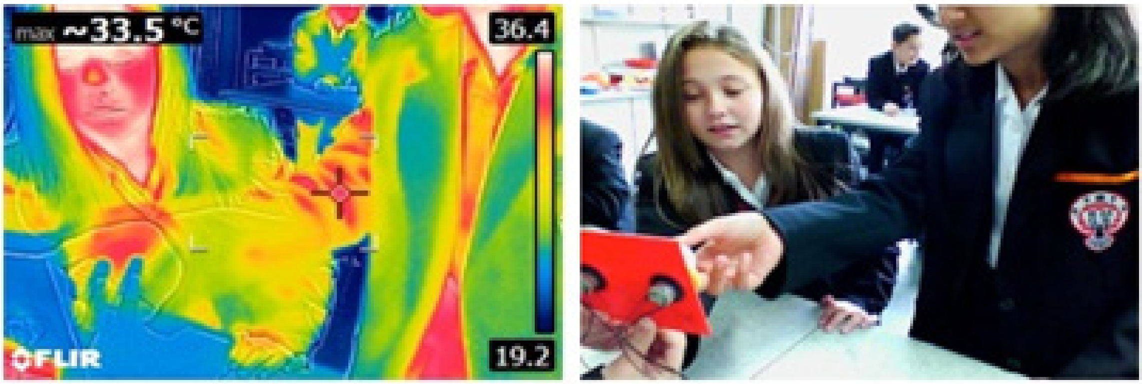

Figure 4: Conservation of energy.

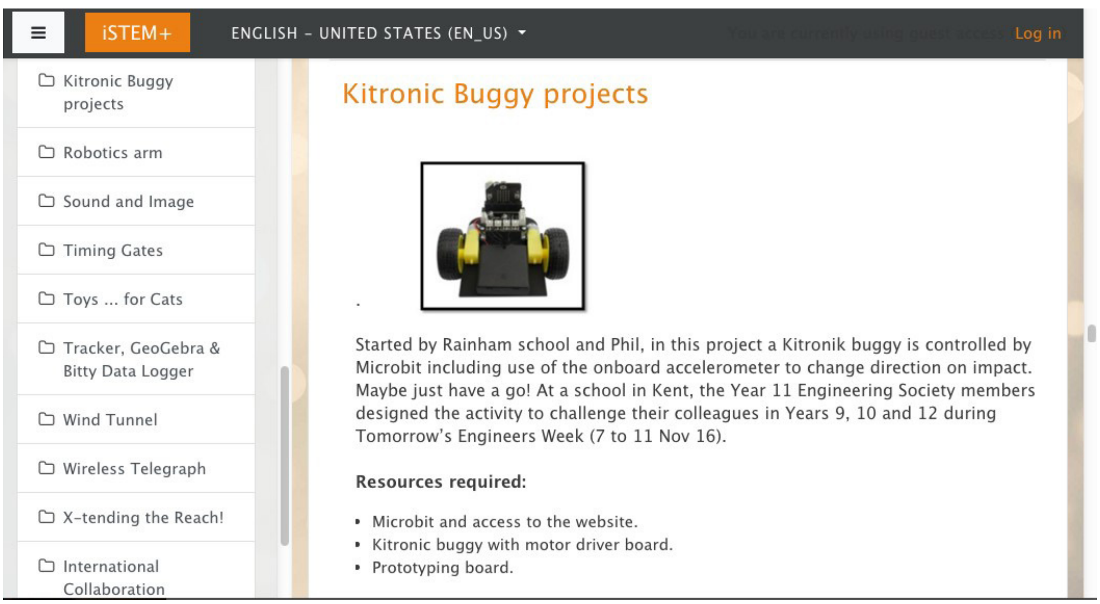

Figure 5: Kitronic Buggy.

most importantly, it increased their self-directed learning, increasing the challenge level but also making the activity much more enjoyable. The intellectual impact was high and transferable skills were acquired.

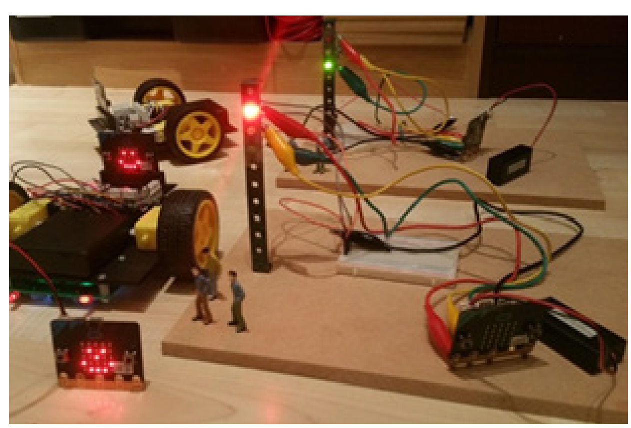

Figure 6: Traffic Lights.

5.3 Traffic lights problem

In a STEM club kick-off meeting with teacher Matt Wells at Rainham School for Girls, the discussion was the "grand challenges" for future engineers, one of which is future cities. We explored future transport and driverless vehicles, and the girls in the STEM club wanted to explore the wider challenges of driverless cars for society, a task with significant cross-curricular potential. The task

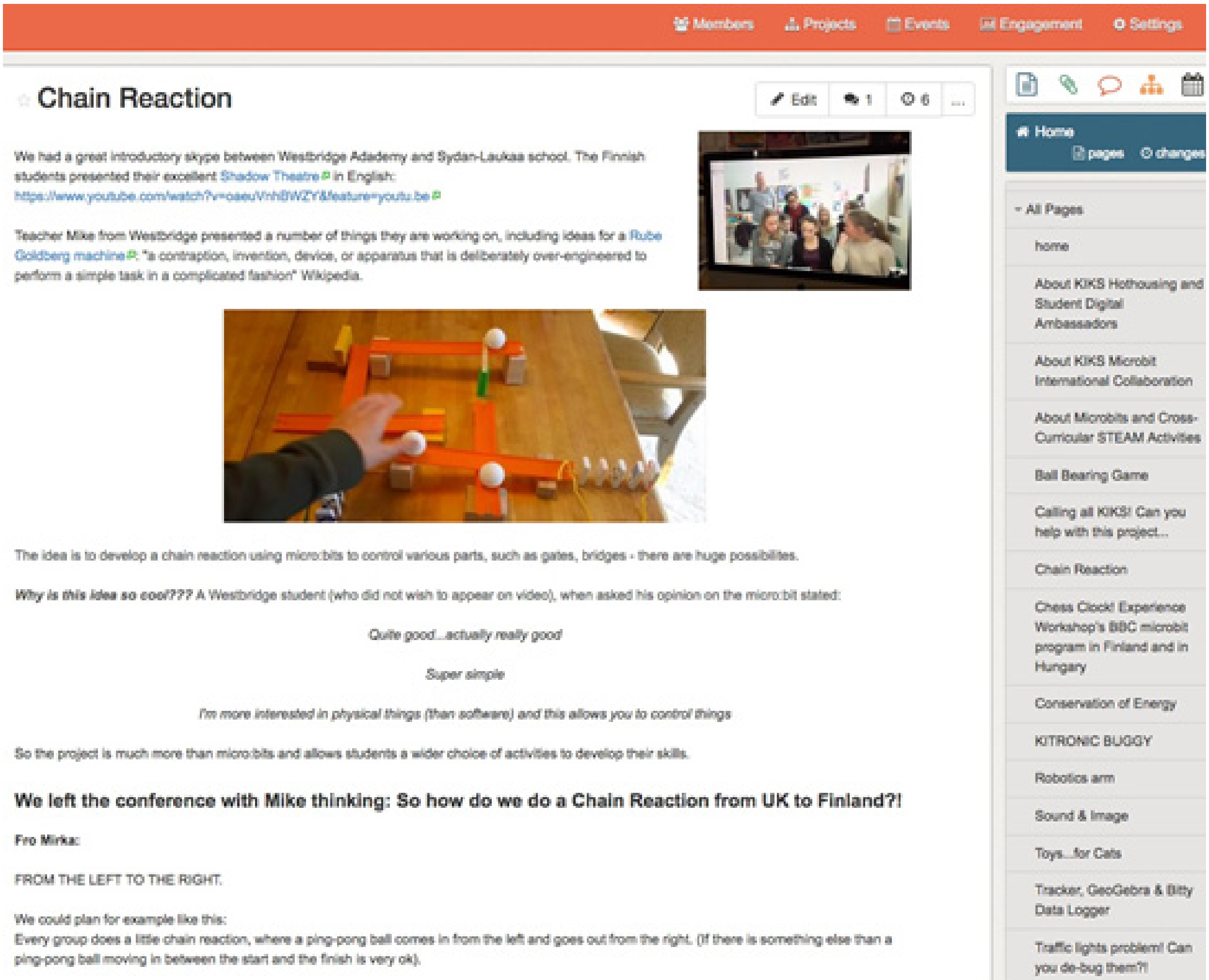

Figure 7: Chain reaction.

consisted of making a fleet of line following buggies and a small town road system of Micro:bit-controlled traffic lights[4].

6 International Collaboration

The students then shared and enhanced their projects internationally in a number of ways featuring videoconferencing, WIKI and Facebook (replaced at the end of the project with MOODLE for commercial reasons).

6.1 UK Finland VC & Micro:bit Chain Reaction project

During a successful videoconference with Sydan-Laukaa and Westbridge Academy, in which each school presented their work, a joint idea for collaboration presented itself: Chain Reaction – in which, for example, a ball rolls down a slope, hits a domino which in turn triggers another event and so on. The idea is to develop a chain reaction using Micro:bits to control various parts, such as gates and bridges. Indeed, the target is to develop a chain reaction in and across as many schools/countries as possible[5].

4 Materials accessible at: https://istemplus.moodlecloud.com/course/view.php?id=3#section-12

5 http://www.kiks.unican.es/en/sydan-laukaa-westbride-academy/ The collaboration can be seen on: https://istemplus.moodlecloud.com/course/view.php?id=3#section-3

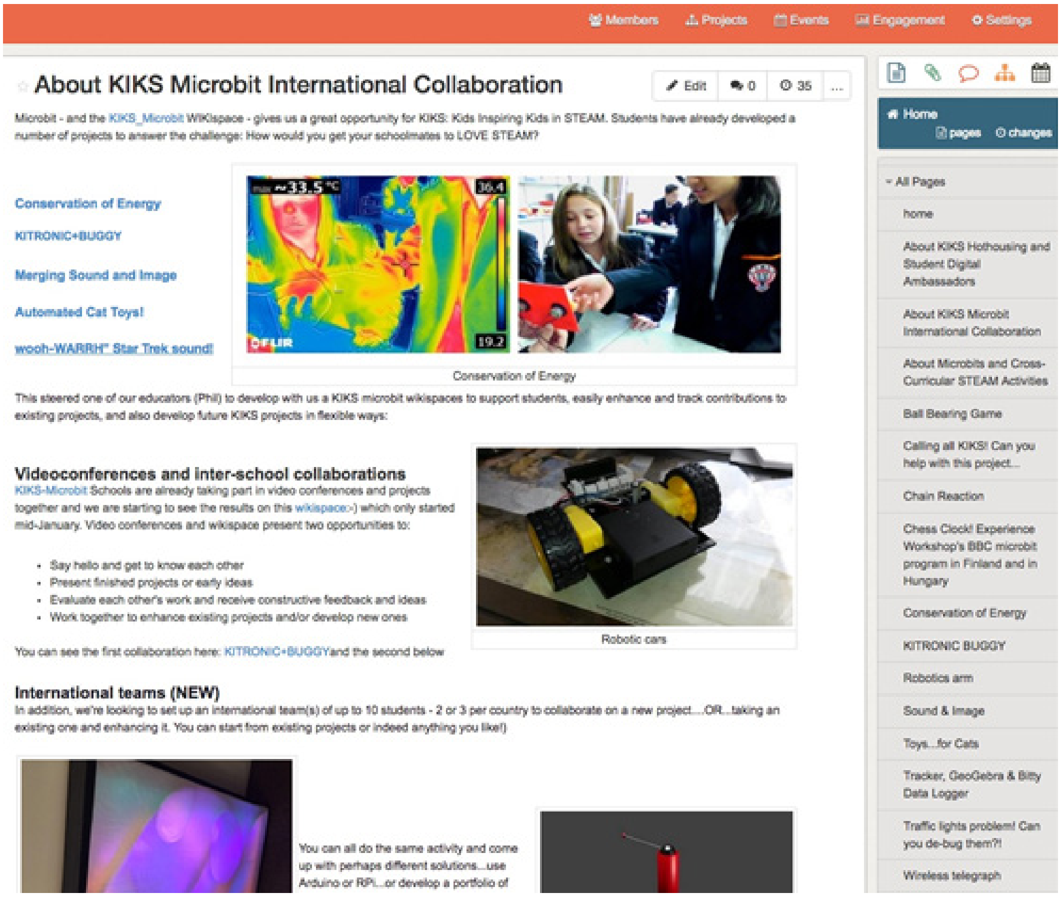

Figure 8: KIKS International Collaboration.

6.2 UK Spain VC & Micro:bit KITRONIK project

Coilegio San Jose presented their work including Wireless Telegraph[6].

Rainham School then described a Kitronik model car/ buggy controlled by Micro:bit including use of the onboard accelerometer to change direction on impact. Building on this original work from Rainham School, Colegio San Jose has contributed to the KITRONIK Buggy project with a soldering activity to be followed by coding[7].

6.3 Video Conferences & Many-to-many Projects

We developed a UK-Finland-Spain-Hungary KIKS Micro:bit project in which the Micro:bit foundation kindly supported and supplied us with 400 Micro:bits[8].

7 Evaluation

The visible results of KIKS can be seen above in the very diverse student-developed projects and the international collaborations. The wide range of projects and international collaboration was mirrored by variants in the Hothousing process, time spent (on average 18 months), student completion (some students came in and out of the project as planned by teachers) and teacher

6 Materials accessible at: http://www.kiks.unican.es/en/wireless-telegraph/

7 The video can be seen at the periodically updated: https://istemplus.moodlecloud.com/course/view.php?id=3#section-12 **http://www.kiks.unican.es/en/rainham-school-colegio-san-jose/**

8 Materials accessible at: https://istemplus.moodlecloud.com/course/view.php?id=3#section-21

STEAM objectives. This makes it challenging to draw conclusions. Nevertheless we could identify a number of valuable results.

7.1 Hothousing Process; 90% completion rate

Taking the Hothousing process as a three-stage Hothouse (to come up with ideas), Local Challenge (to develop a solution(s)) and International Collaboration (On-line and/or face-to-face): 90% of 40 schools completed with 4 unable to complete for management/time reasons. The 90% completion rate compares favourably against similar educational programmes, where engagement is significantly lower.

7.2 Hothousing for both mainstream schools and excluded students

Although limited to the UK participation of special needs schools, the project attracted 100% state schools and both STEAM specialist and non-specialist teachers. The schools ranged from local community colleges (2) to special needs schools (3). It may be that the one-to-one 'child- centred' approach undertaken in special needs schools is compatible with the KIKS approach. This is in contrast to many similar STEM or business projects aimed at schools, which attract more private fee-paying schools with sometimes more motivated teachers and students than hard-pressed state schools.

7.3 International on-line collaboration

Videoconferencing provided an unanticipated richness of experience in the quality of the videoconference presentation and also the Question/Answer sessions, which covered technical, career and personal interests. A one-hour session typically featured a 20-minute presentation and a 40 minute Q&A session. The KIKS Facebook Closed User Group attracted 119 members. The KIKS WIKI on-line collaboration introduced new projects and new participants. It was created for the BBC micro:bit projects only but its potential extends further. The on-line projects contained those from Local Challenges as well as new ones – at the time of writing 21. The on-line "Unique Visitors" were around 20 per day taking May 2017 as an example. This compares favourably with, for example, the UK on-line PREZI report for the KIKS project which attracts on average 10 per month (versus 600 for the WIKI).

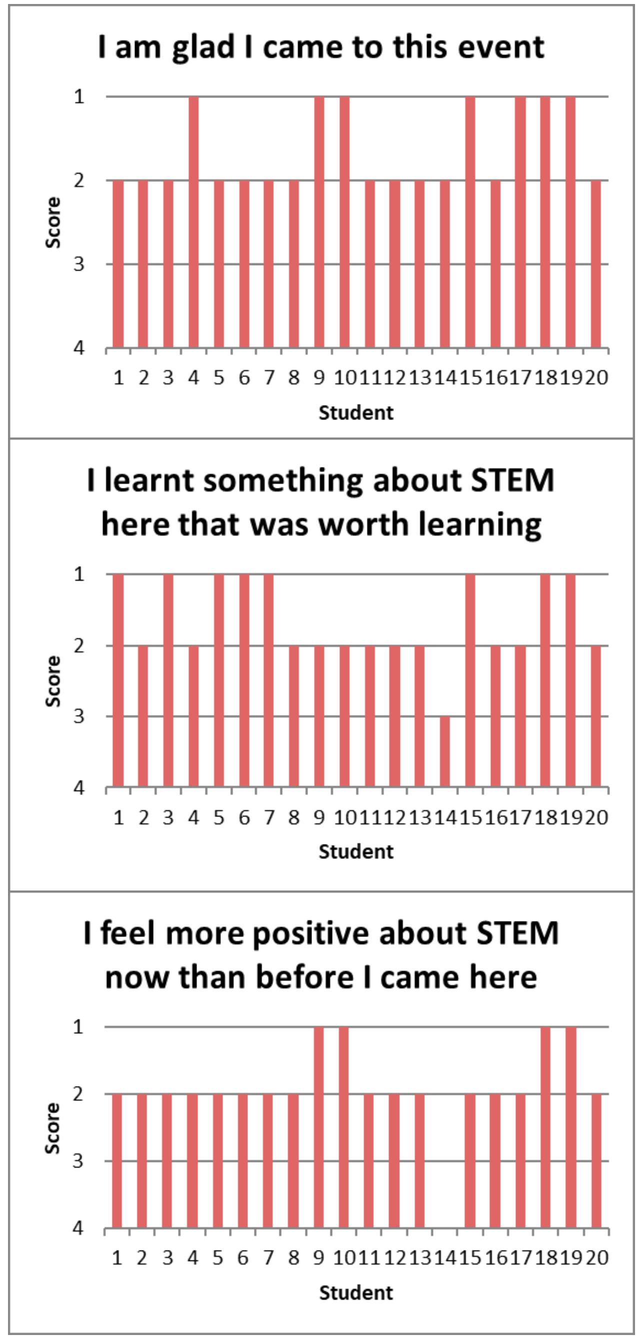

Figure 9: Student responses.

7.4 Positive student response

The Hothousing physical events were much as expected. These activities are well-proven and the feedback shows that this positive reaction is maintained for various activities within the project (Scores: 1 = Highest 4 = Lowest) including the below. Student responses are presented in Figure 9.

7.5 Positive teacher response

Teachers described the KIKS process as providing a good inspiration, wide learning experience and impetus to undertake STEAM activities. The activity was judged to provide specific national curricular contributions and also international benefit. The project did not require extra work from the teachers because students did the work and it was a challenge for able students to work with less able ones and learn from the experience.

8 On-going Work and Future Directions

Key to the support process is the introduction of user-friendly technologies such as Micro:bit Tracker and GeoGebra. As a relative newcomer and addition to the already proven Tracker and GeoGebra, over and above any technological excellence or superiority, Micro:bit has proved to be very user-friendly – with take-up by both the technologically savvy and the relatively inexperienced with technology, in a wide range of STEAM activities. It also spawned a KIKS Moodle Micro:bit activity featuring over 30 projects. The combination of these proven tools featuring technical power and ease of use, supporting projects to excite/engage students plus collaboration between students in physical and virtual teams, can be extended to other technologies which we can "cherry pick" – an obvious contender is 3D printing.

Simulation software and graphical programming environments offer an even bigger opportunity to extend students' experiences merging technology and creativity. This is supported by research on younger students developing computer animations of realistic motion of objects, such as the Playground series of project undertaken by Hoyles (2018). We are using this and the KIKS experience to develop a new approach to the mathematics of motion within a pilot for young students (Oldknow 2019). The first step is to use a physics microworld, such as the free Algadoo software, to put objects into motion under gravity. This enables initial parameters to be set up and provides real-time simulation as well as output of displacement, velocity and acceleration graphs and trajectories. This enables learners to use this laboratory to gain both a qualitative and a quantitative understanding from the simulation, just as professional engineers and designers do in the real world of product development. They then take video clips of real objects in motion, use Tracker to capture position and motion data, and use GeoGebra to fit algebraic models to the data. They can confirm the match between the graphs drawn in GeoGebra with those produced in Algodoo, thus obtaining an algebraic formulation of the equations of motion of their chosen object. Finally they use their equations within a graphical programming environment, such as Scratch 3, to produce their own realistic animations of objects in motion. Such projects allow them to experience the kinds of techniques and skills used by software engineers in the video, games and special effects industries.

The international activities in KIKS spawned the need for communications technology both safe and secure (both actual and perceived), allowing and encouraging collaboration, with videoconferencing and collaborative project/WIKI type activity. Our KIKS online collaboration featured highly successful videoconferencing (but required teacher presence with all students) and WIKI/Moodle (although it was mostly teachers who uploaded content on behalf of students). GeoGebra, the widely used mathematics software originating and centred at our partner University of Linz, has evolved naturally since the original KIKS project and might now be described as the Facebook of Maths and STEAM. In particular, it appears to provide us with the key requirement of a safe and secure (both actual and perceived) environment.

9 Conclusions

Engaging all children requires a process and tools which support creative problem solving in STEAM. It has been very roughly estimated that STEM or STEAM activities typically have at best 50% take-up by schools; teachers are (understandably) too busy and/or lack the confidence to undertake them. In contrast, the KIKS Hothousing approach achieved a 90% completion rate. The project attracted both STEAM specialist and non-specialist teachers. Similarly, the schools ranged from local community colleges to special needs schools. This is in contrast to many similar STEAM or business projects which attract well-funded schools, with already specialist teachers and talented students.

The Hothousing process allied with existing and new tools gives us the potential to provide a rich STEAM educational experience for all young people merging technology and creativity as predicted by Ada Lovelace over 150 years ago.

References

Alsina, C. (2002). Too much is not enough: Teaching maths through useful applications with local and global perspectives. *Educational Studies in Mathematics, 50*(2), 239-250.

Bakar, K. A., Ayub, A. F. M., & Tarmizi, R. A. (2002). Exploring the effectiveness of using GeoGebra and e-transformation in teaching and learning Mathematics. *Proc. of Intl. Conf. of Advanced Educational Technologies EDUTE, 2,* 19-23.

Escuder, A. & Furner, J. M. (2011). The Impact of GeoGebra in Math Teachers' Professional Development. Ph.D. dissertation. Florida Atlantic University 2011 http://archives.math.utk.edu/ICTCM/VOL23/S113/paper.pdf

Grabmeier, J. (2017). International science collaboration growing at astonishing rate. *https://phys.org/news/2017-02-international-science-collaboration-astonishing.html*

Houghton, A. (2014). The Impact of GeoGebra. *https://prezi.com/bsi-qdd6jr6r/the-impact-of-geogebra-evidence/*

Houghton, A. (2017). Kids Inspiring Kids in STEAM. *https://prezi.com/jnd6nez1oz11/kiks-kids-inspiring-kids-in-steam-uk/*

Houghton, A., & Oldknow, A. (2014). PISA STEM and Math/ Technophobia – how do we take the fear out? *GEOMATECH National Hungarian Maths Project Presentations December 2014 in Hungary Kaposvár, Nyíregyháza and Sopron.*

Hoyles, C. (2018). Transforming the mathematical practices of learners and teachers through digital technology. *Research in Mathematics Education, 20*(3), 209-228, DOI: 10.1080/14794802.2018.1484799

Isaacson, W. (2014). The Innovators. *Simon and Schuster UK Ltd.*

Lander, J. (2016). Students as Teachers: Exploring the mutual benefits of peer-to-peer teaching –and strategies to encourage it. *https://www.gse.harvard.edu/uk/blog/students-teachers*

https://phys.org/news/2017-02-international-science-collaboration-astonishing.html

OECD (2018). The Future of Education and Skills. *https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf*

Oldknow, A. (2017). Modelling Micro:bit sensor data captured with Bluetooth. Tracker, GeoGebra and Bitty Data Logger *https://istemplus.moodlecloud.com/course/view.php?id=3#section-17*

Oldknow, A. (2019). STEM Masterclass. *https://www.stem.org.uk/community/groups/99628/stem-masterclasses-ks2-and-ks3/452623*

Oldknow, A. & Houghton, A. (2012). Analysing Sporting Performance. *https://sites.google.com/site/cciteasp2/*

Thomas, M. (2013). Hothousing: New Concept or New Word? *https://www.captechconsulting.com/blogs/hothousing-new-concept-or-new-word*

Wooley, M. (2017). Bitty Data Logger Apps *http://www.bittysoftware.com/apps/bitty_data_logger.html*

Young, C. B., Wu, S. S., & Menon, V. (2012). The neurodevelopmental basis of math anxiety. *Psychol Sci. 2012 May 1; 23*(5), 492-501. *doi: 10.1177/0956797611429134. Epub 2012 Mar 20.*