Institution: Nottingham Trent University (NTU)

Unit of Assessment: B11 – Computer Science and Informatics

Title of case study: Designing and developing accessible and AI-enabled learning platforms that improve the outcomes of children and adults at risk of exclusion.

Period when the underpinning research was undertaken: 2005 - 2020

Details of staff conducting the underpinning research from the submitting unit:

Names:	Roles:	Periods employed by submitting HEI:
David Brown	Professor	2000-Present
Lindsay Evett	Principal Lecturer	2000-2013
Tom Hughes-Roberts	Senior Lecturer	2014-2019
Mufti Mahmud	Senior Lecturer	2018-Present
Eiman Kanjo	Associate Professor	2014-Present
Helen Boulton	Associate Professor	2000-2019
Nadja Heym	Senior Lecturer	2014-Present
Nicholas Shopland	Research Fellow	2000-Present
Andy Burton	Research Fellow	2010-Present
Joe Sarsfield	Research Fellow	2018-2019
Mohammad Taheri	Research Fellow	2017-2020

Period when the claimed impact occurred: 2014 – 31 December 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact

Research by NTU's Interactive Systems Research Group has improved the inclusion of students with learning disabilities and autism in special and inclusive classrooms via approaches to designing accessible and adaptive learning technologies, which improve and enhance their engagement in learning. These are incorporated into:

- An award-winning educational coding app (Pocket Code) that has been downloaded more than one million times across 180 countries.
- A dedicated version of Pocket Code with embedded accessibility features for formal learning environments (Create@School) with over 10,000 installs.
- Adaptive learning platforms (including MaTHiSiS and Pathway+) that have supported inclusive teaching practice, and improved engagement, achievement, and behaviour for students with learning disabilities and autism in schools in Spain, Italy, Bulgaria, Turkey, Belgium, and the UK.
- An app (BuddyConnect™) to support the mental wellbeing of those experiencing workplace anxiety being developed by a world-leading IT services provider.

2. Underpinning research

Access to appropriate ICT-based solutions provides perhaps the only chance for students with a range of physical, sensory, communication and cognitive disabilities of participating in society and realising their full potential. A 2015 Deloitte and Ipsos MORI study prepared for the European Commission highlighted the need to integrate inclusive, personalised ICT solutions into learning environments for children ("2nd Survey of Schools: ICT in Education - Objective 2: Model for a 'highly equipped and connected classroom'" ISBN 978-92-79-99710-5).

Led by Brown, research at NTU cutting across multimodal affect recognition, serious games, location based services, digital game-making, robotics and accessibility has focused on using Artificial Intelligence (AI) to understand how engaged learners are, and how best to target novel ICT interventions at pupils in the greatest need. The overarching aim is to ensure that everyone, especially those with specialised learning needs, has an opportunity to reach their full potential through the support of personalised digital learning platforms.

The development of guidelines, requirements, and user models to promote the accessibility of web content and interactive media by people with a range of cognitive, physical, and sensory impairments is a cross-cutting theme at NTU (**R1**). NTU was one of two universities in the EU FP7 project AEGIS – Open Accessibility Everywhere (2008-2012), using its research experience in promoting accessibility of people with learning disabilities (**G1**). An Open Accessibility Framework (OAF) was developed to embed accessibility solutions into mainstream ICT products. The aim was to place users and their needs at the centre of all ICT developments by making accessibility open, personalised, and configurable. Working within special schools in Nottingham, Brown led the development of 'digital personas' and accessibility guidelines to help ICT designers understand the needs of those with accessibility requirements and posited that their adoption has the potential to improve accessibility for all (**R1**). This approach was subsequently extended to making digital game-making tools more accessible for students with learning disabilities (**R2**).

Brown led a programme of research, supported by seven EU grants totalling £1.5M between 2006 and 2016 (in addition to **G1**-**G4**), into serious games or games-based learning, demonstrating that their use can have a positive effect on deficits in decision-making skills that can otherwise hinder the inclusion of students with learning disabilities in society (**R3**). Through EU project Game On Extra Time (EU Leonardo Transfer of Innovation Project, 2008-2010, coordinated by Brown), researchers developed 10 serious games to support people with learning disabilities and additional sensory impairments to obtain, and retain, a job. The games helped participants to learn skills that would assist them in their working day. The RECALL project (**G2**), led by NTU, came in response to people with learning disabilities being excluded from learning opportunities and community events because they cannot travel independently. Brown's group demonstrated the viability of combining games-based learning with location-based services to help young adults with intellectual disabilities plan travel routes within their local community facilitating the development of cognitive maps (**R4**). In another EU project led by NTU (EDUROB, 2013-2016), researchers found that engagement of children with intellectual disabilities can be significantly improved using programmable humanoid robots (**R5**).

The combined research outlined above shaped the design and delivery of two key EU Horizon 2020 projects, the No One Left Behind project (**G3**) and MaTHiSiS (**G4**). The No One Left Behind project (**G3**) involved a three-country controlled study that explored the benefits of using digital game-making tools within a formal learning environment. Children used a gaming toolkit called Pocket Code, which allows users to create, play and share games in a LEGO-style programming environment, to develop inclusive games on mobile devices. Brown led the UK element of the study involving 200 children with a range of learning disabilities, which found that digital game-making significantly improves the engagement and collaborative behaviours of students in special educational schools (**R2**).

Sustainable learning in students with learning disabilities and autism can only occur when there is meaningful engagement, which, in turn, can help reduce stress and anxiety. The MaTHiSiS project (EU H2020; 18 partners from 9 EU countries) (**G4**) developed a novel AI-enabled learning platform capable of monitoring and responding to an individual learner's mood and behaviour to provide a personalised learning experience. As part of a wider consortium coordinated by IT firm Atos Spain, Brown's group demonstrated that engagement does increase when activities are tailored to the personal needs and emotional state of students with learning disabilities and autism using multimodal affect recognition (**R6**), and that these affect-sensitive algorithms can also be used to infer anxiety.

3. References to the research

Underpinning research quality is evidenced by rigorously externally peer-reviewed outputs.

R1. (Accessibility) Evett L and Brown DJ (2005), Text formats and web design for visually impaired and dyslexic readers—Clear Text for All. *Interacting with Computers* 17, pp.453-472, https://doi.org/10.1016/j.intcom.2005.04.001

R2. (Digital Game Making) Hughes-Roberts T, Brown DJ, Boulton H, Burton A, Shopland N and Martinovs D (2020), Examining the Potential Impact of Digital Game Making in Curricula Based Teaching: Initial Observations. *Computers and Education*. https://doi.org/10.1016/j.compedu.2020.103988
R3. (Serious Games) Standen PJ, Rees F, Brown DJ (2009), Effect of playing computer games on decision making in people with intellectual disabilities. *Journal of Assistive Technologies*. 3(2), pp.4-12, https://doi.org/10.1108/17549450200900011.
R4. (Location Based Services) Brown DJ, McHugh D, Standen P, Evett L, Shopland N and Battersby S (2011), Designing Location based Learning Experiences for People with Intellectual Disabilities and Additional Sensory Impairments. *Computers and Education*, 56(1), pp.11-20. ISSN 0360-1315. http://dx.doi.org/10.1016/j.compedu.2010.04.014.
R5. (Robotics) Hughes-Roberts T, Brown DJ, Standen P, Desideri L, Negrini M, Rouame A, Malavasi M, Wager G and Hasson C (2018), Examining Engagement and Achievement in Learners with Individual Needs through Robotic-Based Teaching Sessions. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.12722
R6. (Multimodal Affect Recognition) Standen PJ, Brown DJ, Shopland N, Burton A, Taheri M and Boulton H (2020). An evaluation of an adaptive learning system based on multimodal affect recognition for learners with intellectual disabilities. *British Journal of Educational Technology Special section on AI and Deep Learning in Education Technology Research and Practice*. https://doi.org/10.1111/bjet.13010

The high quality of the underpinning research is further indicated by the following major funding investment in the research and its dissemination.

G1. EU FP7. AEGIS – Open Accessibility Everywhere. Awarded 1/05/11, value to NTU £141,802. David Brown PI.
G2. EU LLP KA3 ICT. RECALL – Reconnecting Communities And Lifelong Learning Using Android. Awarded 1/11/09, total value £523,146, David Brown PI.
G3. EU Horizon 2020. No One Left Behind. Awarded 1/01/15, value to NTU £457,200, David Brown PI.
G4. EU Horizon 2020. MaTHiSiS: Managing Affective-learning THrough Intelligent atoms and Smart InteractionS. Awarded 1/01/16, value to NTU £552,658, David Brown PI.

4. Details of the impact

The user experience and educational inclusion of students with learning, physical and sensory impairments have improved via research in accessibility

Through the No One Left Behind project, NTU researchers led by Brown worked with children with learning disabilities to build a detailed understanding of their needs in using the digital game-making app Pocket Code. As well as embedding accessibility features in Pocket Code itself, the educational potential of the Pocket Code platform was exploited by developing a dedicated version for formal learning environments called Create@School. Targeted at children aged 9 to 18, this app was designed to enable teachers to integrate gamification into the classroom, leading to improved academic and behavioural outcomes for students with learning disabilities (**S5**, **S6**). Based on the research findings, Brown's group developed novel accessibility features for the Create@School app (**S1**). These included the option to create bespoke profiles for users with specific needs, including Argus (colour vision impairments), Odin (general vision impairments), Fenrir (motor skills impairments) and Tiro (cognitive impairments), together with a range of other accessibility features: larger text, high contrast, additional icons, large icons, large spacing, drag´n´drop delay and Beginner Mode. Designing for disability commonly improves accessibility for a wider population and Catrobat (the app developer), also embedded the new accessibility features into the main Pocket Code app in 2016 (**S1**).

The significance of NTU's research contribution is captured in a statement from the Catrobat President (**S1**): "*Before our joint project, there were no provisions in Catrobat's Pocket Code app for users with special needs such as learning and physical disabilities. Our partnership … allowed*

us for the first time to understand the end user requirements of such users" (with a learning, physical or sensory impairment). He said NTU's evaluation methods "*contributed to a significant degree to the success of the project*", adding: "*Our international partners in India, Thailand, Tanzania, Pakistan, Jordan, and the US, in the US in particular at Google and with the Scratch team at the MIT Media Lab, were highly impressed with these extensive new accessibility features*."

According to Catrobat (**S1**), "*The accessibility features have since contributed to the successful deployment of our apps and services in all regions where we are active*." As of 20th October 2020, the Pocket Code app with NTU's accessibility features now embedded, had been downloaded over one million times in more than 180 countries (**S1**). The app has an average rating of 4.1 stars out of 5 from 18,743 users (**S2**). There are also over 10,000 downloads of Create@School - the dedicated version for formal learning environments (**S3**). Catrobat's President said: "*NTU's research contributions thus have helped tremendously to promote the adoption of our app by schools and have contributed to the apps winning 6 international prizes and awards*." These have included Winner of the 2016 Regional Award Europe at the global Reimagine Education Awards, run by University of Pennsylvania, two Lovie Awards (for ICT) from the International Academy of Digital Arts and Sciences, London, and Platinum Award winner in the 'Best Educational App' category at the 2017 Best Mobile App Awards. Finally, in December 2020, Pocket Code won Best App Award in Europe in the HMS App Innovation Contest by Huawei (**S4**).

Academic and behavioural outcomes for students with learning disabilities have improved, and educational practices have changed via our research in digital game making, serious games, location-based services, robotics, and multimodal affect recognition

Both the Create@School and Pocket Code apps have provided teachers of students of all abilities with support in teaching coding and computational thinking. The No One Left Behind project created a game-making teaching framework comprising a three-step methodology to integrate the apps into classroom practice. Inmark's Director of Innovation Management (**S5**) said: "*NTU's evaluation methods applied to the 'No One left Behind' pilots' evaluation across Europe had a significant impact to the adoption and sustainability of the create@school App. This resulted in educational benefits, namely improved engagement, persistence, confidence, collaborative behaviours, and deeper understanding of subject knowledge*."

One of the UK schools that participated in No One Left Behind was Oak Field School, a local authority school in Nottingham providing for 160 students with severe, profound and complex, physical and learning disabilities. The school's head (**S6**) said the game-making within Pocket Code had provided "*clear evidence of improved behaviour*" and "*deeper understanding of subject knowledge*" among students, and that teachers found it had "*developed their (own) awareness of the potential of the pupils at school*".

The provision of personalised learning experiences through NTU's research contributions in multimodal affect recognition in the MaTHiSiS platform resulted in higher levels of student engagement and improved learning outcomes. To evaluate the impact of the platform, 21 teachers across the UK, Spain and Italy who work with students with special educational needs were interviewed. The Head of Public Administration Market for Atos (**S7**) said of the teachers: "*They reported that the system promoted students' desire to participate, improved achievement and helped with difficult behaviour; and revealed skills, knowledge and abilities in these students that teachers had not otherwise understood or realised*". She also confirmed that, "*The NTU contribution to this project was demonstrably material to the impact*".

In collaboration with Nottingham Schools' Trust, NTU has identified areas for the improvement of educational outcomes for all pupils by exploring the adoption of alternative and new ways of working using AI-enabled adaptive learning platforms, serious games and social robotics to improve the inclusion, and academic and behavioural outcomes for students with a range of learning disabilities. The Chief Executive Officers of Nottingham Schools Trust confirmed that "*David* [Brown]*'s work has impacted the work of Nottingham Schools' Trust in relation to our work*

with 36 unique schools across the city that make up the Nottingham Schools Trust", and added that, "*Teachers from our Trust have reported that Nottingham Trent University's research has resulted in: A way to engage students with autism via their research in robotics. A specific way of assessing and supporting pupils with Speech and language difficulties … An app to help identify students who are not engaged in learning … Apps that have immediate application in our classrooms*" (**S8**). They further confirmed that NTU's research has resulted in, "*an incredibly useful resource in terms of games and apps which are freely available for schools*" (**S8**).

Our research in multimodal affect recognition has more recently contributed to the innovation and entrepreneurial activity of a world leading IT Services provider. In 2019 Fujitsu, who support 7.5 million end users globally, began to integrate NTU algorithms to infer workplace anxiety into its services to support workers operating in highly stressful situations. The 'BuddyConnect™' App is under development. This uses Heart Rate and Heart Rate Variability sensor data and machine learning to infer anxiety, then launches recommendations for evidence based psychological interventions when the need arises for improved workplace mental wellbeing. Fujitsu has invested £50,000 (31/12/20) in the development of this App (**S9**).

5. Sources to corroborate the impact

S1.* Testimonial letter: President of International Catrobat Association, Austria
S2. Web-link: https://play.google.com/store/apps/details?id=org.catrobat.catroid&hl=en_GB&gl=US
S3. Web-link: https://play.google.com/store/apps/details?id=org.catrobat.catroid.createatschool&hl=en_GB&gl=US
S4. Web-link: https://www.xda-developers.com/apps-up-2020-contest-winners/
S5.* Testimonial letter: Director Innovation Management, INMARK, Spain
S6.* Testimonial letter: Head Teacher, Oak Field School & Sports College, Bilborough, UK
S7.* Testimonial letter: Head of Public Administration Market, Research and Innovation, ATOS, Spain
S8.* Testimonial letter: Chief Executive Officers, Nottingham Schools' Trust
S9.* Testimonial letter: Head of Strategic Development and Innovation, Global Delivery - Workforce and Workspace Services, Fujitsu, UK

(* participant in the process of impact delivery)