Institution: University of Bristol		
Unit of Assessment: 23) Education		
Title of case study: Incorporating neuroscientific understanding in educational theory and practice		
Period when the underpinning research was undertaken: 2010 - 2018		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Paul Howard-Jones	Professor of Neuroscience and Education	01/2003 - present
Rafal Bogacz	Reader in Computational Neuroscience	02/2004 - 09/2013
Tim Jay	Senior Lecturer in Psychology of Education	09/2008 - 09/2014
Ute Leonards	Professor of Neuropsychology	04/2003 - present
Period when the claimed impact occurred: 2013 - 2018		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

Insights from neuroscience, including the role of reward and 'gamification' for learning, are essential to inform effective approaches to education. Educational neuroscience research from the University of Bristol (UoB) (i) underpinned decisions by two UK NGOs to provide large-scale, innovative funding to inform national teaching practice and education policy; and (ii) contributed directly to innovative continuing professional development and initial teacher development. Take-up of these new approaches to teaching and learning has reduced misunderstanding about how the brain learns and raised the awareness of both practitioners, and the public, of the importance of neuroscientific evidence for education. Our UoB research has also informed international educational policy and practice regarding teacher education.

2. Underpinning research

Myths about the brain – neuromyths – often persist in schools and colleges and can result in the use of ineffective approaches to teaching. Howard-Jones has been an influential advocate of the establishment of a field of enquiry dedicated to bridging the gap between neuroscience and education [3]. A particular focus of his research has been the link between reward and learning, and the use of game-based interventions, to motivate and improve the outcomes of learners.

The link between reward and learning has chiefly been studied in the context of learning to maximise reward. This type of learning, which we share with animals and relies on mid-brain response, differs greatly from the learning valued by educators, which typically involves memory of knowledge and understanding that can be declared and explained.

Using functional Magnetic Resonance Imaging (fMRI) to monitor brain activity Howard-Jones demonstrated an association between gamification (embedding learning in game-like activities) and deactivation of default mode network (DMN) regions in the brain [5], as well as increased engagement self-reported by participants. An earlier classroom study revealed that electrodermal activity (signalling emotional response) is further increased in participants when reward is uncertain [1], and a behavioural study of adult learning showed the potential of reward-based neurocomputational models of behaviour in the understanding and development of effective learning games [2].

This scientific work identifying new links between reward and learning has been complemented by critical analysis of how ideas about neuroscience can be interpreted and sometimes

misinterpreted in the classroom [3, 4]. A review of educational interventions and approaches informed by neuroscience [4] carried out on behalf of and funded by the Education Endowment Trust [i], highlighted challenges in bridging the neuroscience-education gap using randomised controlled trials. A key issue encountered when implementing ideas from neuroscience in the classroom was the level of understanding possessed by teachers about the scientific basis of learning [3].

To tackle the issue of neuromyths and improve scientific understanding of learning amongst teachers, Howard-Jones spent three months (October – December 2016) as Senior Fellow at the International Bureau of Education (IBE), during which he developed and introduced novel concepts suitable for communicating with teachers about how learning proceeds, and how this may contribute to student engagement.

3. References to the research

[1] **Howard-Jones PA** & Demetriou S. (2009). Uncertainty and engagement with learning games. *Instructional Science*, 37(6), 519-536. DOI:10.1007/s11251-008-9073-6 [107 citations] (all citation figures as of 14 April 2020)

[2] **Howard-Jones PA,** Demetriou S, **Bogacz R**, Yoo JH, **Leonards U**. (2011). Toward a Science of Learning Games, *Mind, Brain and Education,* 5(1), 33-41. DOI:10.1111/j.1751-228X.2011.01108.x [79 citations]

[3] **Howard-Jones PA.** (2014). Neuroscience and education: myths and messages. *Nature Reviews Neuroscience,* 15(12), 817-824. DOI:10.1038/nrn3817 [210 citations]

[4] **Howard-Jones PA.** (2014). Neuroscience and Education: A Review of Educational Interventions and Approaches Informed by Neuroscience. Education Endowment Foundation. Available from: https://educationendowmentfoundation.org.uk/public/files/Application_Guidance/Neuroscience_Literature_Review [51 citations]

[5] **Howard-Jones PA**, **Jay T**, Mason A, & Jones H. (2016). Gamification of learning deactivates the Default Mode Network. *Frontiers in Psychology*, 6, 1891. DOI:10.3389/fpsyg.2015.01891 [34 citations]

[6] **Howard-Jones PA** & **Jay T**. (2016). Reward, learning and games. *Current Opinion in Behavioral Sciences,* 10, 65-72. DOI:10.1016/j.cobeha.2016.04.015 [20 citations]

Research Funding:

[i] **Howard-Jones P**. Engaging the Brain's Reward System, EEF & Wellcome Trust, 2014 – 2017, GBP650,000

[ii] **Howard-Jones P** (co-app). Science of Learning – a massive open online course for teachers, Wellcome Trust, 2017 – 2018, GBP10,000

[iii] **Howard-Jones P.** Science of Learning into Initial Teacher Education, Wellcome Trust 2017 - 2018, GBP30,000

[iv] **Howard-Jones P**. Science of Learning into Initial Teacher Education II, Wellcome Trust 2019 - 2020, GBP43,756

4. Details of the impact

Informed innovative national neuroscience and education funding initiative

The notion that neuroscience can inform education has gained global traction in recent years, but there has been a dearth of research-informed practice in this area. In 2014, The Education Endowment Foundation and Wellcome Trust jointly funded a GBP6 million initiative, spanning Neuroscience and Education that aimed to provide the practical evidence needed on how

neuroscience might improve educational outcomes [A]. Howard-Jones's review [4], which included a rating of current ideas in terms of their evidence-base and their distance to implementation was *"pivotal in [the] decision"* to fund this programme [A]. The review was also used to inform researchers applying for funds within this initiative. The programme funded six projects, including Howard-Jones' research [i], that focused on a large-scale trial involving 44 schools using uncertain reward in Year 8 science lessons [5, 6]. Summaries of the outcomes from these six projects were circulated via the 'Journal of the Chartered College of Teaching (2018). Issue 2: Science of Learning' to all UK schools, thereby supporting teachers to make use of this research in their teaching.

National and international teacher education and professional development

In May 2017, Howard-Jones and Jay, drawing on their research on learning and reward [5, 6], were invited by the Wellcome Trust to act as consultants and presenters for a new MOOC (Massive Open Online Course) run by the National STEM Learning Centre and funded by Wellcome [ii]. The course, on the 'Science of Learning', has allowed teachers from around the world to improve their scientific understanding of reward and other concepts relevant to classroom teaching. The course has attracted 19,708 enrolled participants and 79 reviews, with a rating of 4.9 out of 5 (December 2020) [B]. The STEM Learning Centre evaluation (April 2020) found that 86% of teachers who pursue this course reported agreement with statement; *"My practice of using evidence critically to inform my teaching has changed"* [Cii]. Similarly, 98% of teachers reported an impact on themselves as a result of the course, and 81% reported an impact on their students [Cii]. In an earlier evaluation (July 2018), one participant noted the course had provided; *"More understanding of…the involvement of the reward system on working memory and long-term memory"* and showed more than 60% of MOOC enrolments are non-UK internationals [Ci]. One participant writing on STEM Learning centre blog said of the course: *"Doing this CPD has made me really think about lesson design and for that, I will become a better teacher"*, emphasising a key impact on improving teaching and thereby children's learning [D].

In 2017, Howard-Jones was awarded funds from Wellcome Trust [iii], to incorporate concepts from neuroscience [including 1-6], into the University of Bristol Post-Graduate Certificate in Education (PGCE), reaching approximately 165 student teachers per year [A]. This project also developed guidelines for other teacher education institutions to follow Bristol's example and, in 2019, the Wellcome Trust funded an extension to this work [v] to demonstrate its application in mentoring student teachers on school practice. Videos of mentors drawing on the concepts have now been published [Ji] as a resource for teachers when debriefing student teachers following classroom observation. From September 2019, Bath Spa University adopted the concepts for presentation to all their student teachers during the taught phase of their courses, training around 250 teachers each year [Jii], and another 10 teacher training institutions have invited the project team to present the concepts to their staff with a view to including these in their Initial Teacher Education courses. Additionally, the extension project team has been funded by the Wellcome trust [iv] to liaise with, and promote their work to, key stakeholders (including OFSTED, DfE, Universities Council for the Education of Teachers (UCET) and the Chartered College of Teaching).

Concepts and resources developed to tackle the issue of neuromyths are also being introduced into teacher education in developing countries. Howard-Jones has undertaken five UNESCO-IBE 'missions' (2017-2019) to work with the Seychelles Institute of Education to incorporate the concepts into teacher education, reaching 107 students and 27 members to staff to date [Ei]. IBE see this as a testing ground for efforts to distribute the concepts more widely across Africa and beyond. In 2020-2021, the IBE plan to pilot a teacher training course on the neuroscience of

learning [Eii] using content from Howard-Jones fellowship research and is exploring the possibility to pilot similar courses in Korea and South Africa [Ei]. A planned meeting went ahead online (Oct 2020) organised by the Nicaraguan Ministry of Education with input from Howard-Jones for the delivery of the concepts to teachers in Nicaragua [Eiii]. The IBE often refers to the research in this case study [3, 6], when participating in formal and informal discussions with policy makers and practitioners all over the world. The IBE Director highlights that *"Professor Howard-Jones' IBE work on translated neuroscience knowledge is integrated into the IBE's training courses for teachers and curriculum specialists, placing them at the frontiers of knowledge and practice"* [Ei].

Howard-Jones has also engaged with practicing teachers from schools across the South-West and Midlands to improve understanding and change attitudes regarding scientifically informed practice. Peer-reviewed evaluation of the impact of 1.5 hours of continuing professional development (CPD) on 585 teachers' underlying beliefs found that in comparison to ratings collected before the professional development, 71% of attendees increased the usefulness they attributed to scientific explanations, and 57% reduced the rated usefulness of performative, prescriptive and unscientific ideas [Gi, Gii]. A follow-up within the study, showed this change in beliefs persisted after 6-12 weeks of attendees having returned to work [Gi, Gii]. The Director of a Teaching School Alliance in Bristol, which acts a hub for sharing good practice, noted that research and engagement by Howard-Jones, *'will have an impact on school policies and practice and has inspired colleagues to undertake further study with the University'* [F].

Informed international education policy

During his IBE Fellowship, Howard-Jones contributed knowledge and dissemination materials on using neuroscience to inform IBE's work developing education policy and practice internationally and positively impacting on the understanding and awareness of key stakeholders in relation to education and neuroscience issues. This was achieved through the creation of a 'clearinghouse' for the Sciences of Learning [Iii]; this online portal was launched in 2019 by IBE Director [Ii]. The IBE Director noted that *"Professor Howard-Jones was instrumental in the setting up of this clearinghouse, not only by producing* [six] *briefings to be added to the clearinghouse but also by quality assuring other briefings"* [Ei].

Through his Fellowship, Howard-Jones significantly enhanced the thinking of and debates between international education policy makers, interacting with United Nations senior officials and representatives of the UN Permanent Missions in Geneva and presenting his work at the International Biennial Conference on Early Childhood Care and Education in Seychelles (2017), attended by teachers, educational leaders and policy-makers from across the state [Ei]. In 2019, Howard-Jones presented his work to a High-level Forum at Daegu (South Korea) which, for the first time, brought together over 200 participants from 14 countries, including ministers of education, senior experts on teaching and learning and neuroscientists. Following his presentation a Ministerial Roundtable, attended by ministers of education from Bangladesh, Burundi, Cambodia, Seychelles, South Africa and Zimbabwe, emphasised the importance of using neuroscientific knowledge to guide teaching, learning and assessment, with specific reference to the importance of engaging teachers as presented by Howard-Jones and discussed initiatives to achieve this [Ii].

In recognition of his contribution to the work of the IBE, which the Director reports "*has impacted with considerable and increasing reach and significance in relation to IBE's vision"* [Ei], Howard-Jones has been appointed as a Senior Fellow of the IBE, where he will continue to inform how neuroscience can feed into educational thinking, policy, and practice.

Informed national education policy

Howard-Jones' research has also informed UK education policy debates, including generating "considerable interest" in his contribution at a policy debate on 6 September 2018 with selected researchers and representatives from the Department for Education and Ofsted that aimed to support evidence-based policy making in education [A]. It has also informed the DfE's development of the Early Career Framework for teachers [H] – which underpins an entitlement to a fully-funded two-year package of structured training and support for early career teachers.

Increased public awareness and understanding

Howard-Jones has undertaken a number of high-profile engagement activities that have raised public awareness and understanding of the brain's reward system and its relation to learning. He was a regular presenter on the award winning (Broadcast Award, 2016) and twice BAFTA-nominated (2016, 2017), Secret Life of 4, 5 and 6 Year Olds (developed with the Wellcome Trust and reaching up to 2,300,000 viewers), and co-authored the book of the series. The series (and book) refers to the research featured in this case study [1, 2].

5. Sources to corroborate the impact

[A] Wellcome Trust (2018). Factual statement - Programme Manager, Education & Neuroscience

[B] STEM Learning (2020). Science of Learning Screenshot showing user & review statistics

[C] i) STEM Learning (2018). NE709A17 Science of Learning: Impact Report
ii) STEM Learning (2020). Science of Learning Post-Course Self-Audit - Summary data on impact and general evaluation

[D] STEM Learning Opinions Blog (2018). Engage, build, consolidate bringing learning to life

[E] i) UNESCO/IBE (2018). Factual statement – Director
ii) UNESCO/IBE (2020). Report on Activities and Budget 2019 *(p.16 and 22).*
iii) Nicaraguan Ministry of Education (2020). Letter - Director of Initial Education

[F] Cathedral Schools Trust (2018). Factual statement - Director of Teaching School Alliance

[G] i) **Howard-Jones P, Jay T**, Galeano L. (2020). Professional Development on the Science of Learning and teachers' Performative Thinking - A Pilot Study. *Mind Brain and Education,* 14(3), 267-278. DOI:10.1111/mbe.12254
ii) Galeano (2020). Brief training on the science of learning increases its perceived value and reduces teachers' performative thinking

[H] DfE (2019). Email correspondence - Teaching Profession Unit, Teacher Workforce Development Division

[I] i) UNESCO/IBE (2019). News: IBE-UNESCO leads global dialogue on neuroscience and the future of education and learning
ii) IBE Science of Learning (2019). Effective teaching and its relation to our scientific understanding of learning

[J] i) Science of Learning (2020). Videos: Mentoring Teachers Using Engage Build Consolidate
ii) Bath Spa University (2020). Factual Statement – Reader in Primary Science