Overview and synthesis of the Science of Learning landscape: Bridging interdisciplinary divides

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To appear in: Wei Loong David Hung, Azilawati Jamaludin, & Huang Junsong Davi (Eds.), Scaling System-Wide Education Change in Learning: Convergence of Learning Sciences, Science of Learning, and Science of Systems. Springer.

Word count: 9909

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The Science of Learning aims to understand how new knowledge and skills are acquired and to connect research-based evidence with educational practice. Collaboration between the fields of neuroscience, child development, genetics, psychology, computer science and education – amongst others – provides multidisciplinary methods, expertise, and knowledge to tackle important questions about the learning process.

Each discipline contributes another piece to the learning puzzle. For example, neuroscience helps us understand the specific neural processes that take place in the brain during learning, as well as biological and environmental factors that promote or impede learning. Cognitive neuroscience and psychology are fundamental in determining how the mind processes information and knowledge, including how attitudes, motivation, social interactions, and emotions influence learning. Computer science constructs models to test theories about the learning process, whereas research in education examines learning that takes place in real-world contexts. Ultimately, the goal for the field is to develop effective methods to improve learning experiences and outcomes, while also supporting the learner's health and wellbeing, thereby encouraging human capability and flourishing (UNESCO, 2022).

In the last few decades, innovative hubs across the globe, such as the *Centre for Educational Neuroscience* in the United Kingdom, the *John Hopkins Science of Learning Institute* and *Science of Learning Research Center* in the United States, the *Millennium Nucleus for the Science of Learning* in Chile, the *Science of Learning in Education Centre* in Singapore, and the *Science of Learning Centre* in Australia, to name just a few, have been created to further advance the science of learning and encourage collaboration. New journals (e.g., *Mind, Brain and Education* and *Trends in Educational Neuroscience*) and societies (e.g., *The International Mind, Brain and Education Society*, the *European Association for Research on Learning and Instruction's Special Interest group: Neuroscience and Education*) have been established to support and advance the field. Each consortium adopts different approaches to tackling questions in the Science of Learning. Some take a more interdisciplinary approach, synthesising links between disciplines into a coordinated, coherent whole; others take a multidisciplinary approach, collating knowledge from different disciplines; and others take a transdisciplinary approach to researching learning processes, developing strategies across many disciplines thereby creating a novel holistic approach (Choi & Pak, 2006). What each of these hubs shares is an interest in linking research to real learning situations and thus promoting evidence-led educational initiatives – not just within their respective countries, but as part of a global practice landscape. For example, the *Conexiones* team in Ecuador contributed to the development of UNESCO's Teacher Training Initiative and the MESH Guidance for evidence-informed teaching in England (https://thelearningsciences.com/about-us/?lang=en); the Centre for Educational Neuroscience in London has likewise recently been part of an international collaboration to evaluate the Literacy for Women for Africa programme in Malawi (Rogers et al., submitted for publication), transforming insights from the Science of Learning into 'usable knowledge' within the realm of adult literacy promotion in Africa.

This chapter will explore the current landscape of the Science of Learning, whilst also discussing some of the challenges in bridging interdisciplinary divides within the field. In the first section, we consider the journey from basic research to creating educational interventions and how different disciplines interact in this endeavour. In the second section, we outline why the science of learning must consider the learner in context and describe research that attempts to understand how inter-related factors from the individual to societal level might influence learning outcomes. The third section deals with integration of research into practise, alongside its associated challenges, before concluding with a look to the future and how we envisage the evolution of the field. The broader arguments are illustrated by a series of case studies. Respectively, these span a technique developed from neuroscience principles to enhance children's understanding of counter intuitive concepts in mathematics and science through training their inhibitory control skills; a longitudinal cohort study of teenagers investigating diverse environmental factors that influence cognitive development and educational attainment in a longitudinal cohort study of teenagers; and a holistic intervention based on health mentoring to improve educational outcomes for vulnerable children. Whilst these three case studies feature examples of research which took place in the United Kingdom, they illustrate key principles which form the foundations for all initiatives in the international sphere of the Science of Learning: namely, exemplifying research practices which promote translational knowledge and supporting the evaluation of learning outcomes in ecologically valid educational situations.

From basic science to educational intervention

Supporting educational outcomes involves first understanding the basic science of the learning process. The first step in cultivating this understanding is the identification of a goal or challenge within an educational context, often highlighted by those working in educational settings. From here, researchers can explore the basic mechanisms underpinning the learning challenge through empirical investigation, often in a lab-based environment. The results from the basic research can then be used to create educational interventions, techniques or activities to address the original challenge or goal, requiring input from both researchers and educators.

However, before being introduced to the classroom, interventions require rigorous testing and evaluation. Lab-based feasibility studies, classroom-based pilot studies, efficacy trials and effectiveness trials (Shawn Green et al., 2019), should all be carried out before the intervention can be adapted, usually with commercial support, into a product that can be integrated with educator's current teaching methods, and most importantly, into a product that educators want to use in their practice.

Intervention studies are fundamental in allowing the researcher to better understand causality. In these studies, at least two groups of participants are observed. One group (the intervention group) undergoes a small change in their environment (the intervention), holding all else constant. Any changes in this group can then be compared to the other group(s), who did not receive the intervention. The final step in the journey from research to intervention involves continuous evaluation of the intervention, to ensure the intervention is working optimally and via the supposed mechanisms.

In practice, the process is often less prescriptive and is not without its challenges. Researchers, educators, and stakeholders frequently have differing priorities and perspectives on how intervention research should be conducted and evaluated. To demonstrate this, below we describe the *UnLocke* project as a case study. This project was led by the Centre for Educational Neuroscience in London and funded by the British research charitable foundation the Wellcome Trust and the Education Endowment Foundation (EEF), a UK charity which supports educators by providing evidence-based resources to improve learning. The UnLocke project aimed to support children's science and maths learning, through the creation of "Stop & Think", a computer assisted learning activity. This activity was designed to promote inhibitory control skills (the ability to suppress prepotent responses) when solving counterintuitive problems in science and maths, in children aged 7-8 and 9-10 years old. From identifying the project's feasibility, to testing its efficacy, this project required input from multiple disciplines. In the next section we outline how UnLocke progressed from a classroom observation to research to intervention, followed by a discussion of the challenges which arose because of the transdisciplinary nature of this project.

Case study 1: the UnLocke project

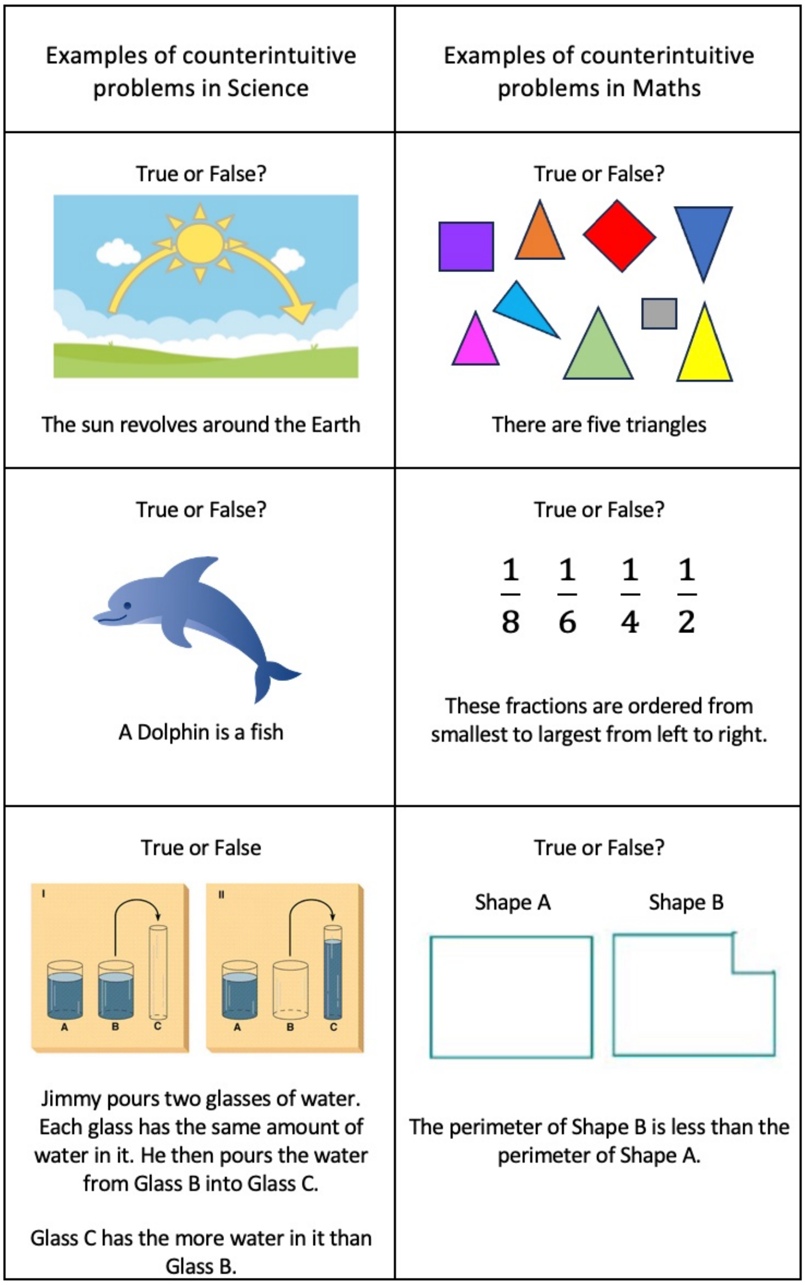
The rationale for this project stemmed from the observation that many children find learning science and maths challenging. One source of difficulty is that conceptual understanding of science and maths often involves learning counterintuitive concepts. Counterintuitive concepts confront already held intuitive theories or beliefs and are thus difficult to comprehend, often due to three types of conflict: a conflict with prior experience, a conflict with prior learning, or a conflict of perceptual salience.

For example, an individual may observe the Sun "rise" and "set" in the sky, and intuitively believe that the Sun revolves around the Earth based on personal experience. However, perhaps in a science class, the child is then taught that the Earth in fact orbits the Sun, which contradicts their prior experience. The Sun seems to drop below the horizon, but science tells us the horizon rises to cover the Sun. Conflicting prior learning can also generate counterintuitive problems. For instance, in mathematics, a child first learns that the positive integer 4 is bigger than the positive integer 3. However, when negative integers are introduced, the child must now learn that -3 is bigger than -4, and when learning about fractions, that 1/3 is larger than 1/4. Finally, perceptual salience can induce conflict and lead to counterintuitive problems. For example, when comparing the perimeters of two shapes, a child may be tempted to think that a shape with a smaller area would have a smaller perimeter. However, the size of shapes does not necessarily correlate with their perimeters. A shape with a smaller area can in fact have the same perimeter as a shape with a larger area (see example in Figure 1). In this case, the child is required to ignore the more salient feature (shape area) to correctly compare the target feature, the shape perimeter. These counterintuitive concepts are demonstrated in Figure 1 alongside other examples.

How can we help learners reason about counterintuitive concepts more effectively? Research on concept learning suggests that when a new concept is acquired, it does not simply replace the old one, but both old and new concepts exist together, and a cognitive control process, such as inhibitory control, is required to suppress the contextually inappropriate concept, so that the correct concept can come to mind given the context (Mareschal, 2016; Potvin, 2013; Shtulman & Valcarcel, 2012). In the classroom, the child might plot the orbit of the Earth around the Sun, for example to understand the seasons, but when walking home, be comfortable to think that the Sun is dropping below the horizon. Inhibitory control is a cognitive process defined as the ability to suppress prepotent responses or interfering thoughts/memories (Gärtner & Strobel, 2021; Nigg, 2000).

Figure 1

Examples of counterintuitive problems in science and maths presented as True or False questions



Behavioural evidence has been collected that demonstrates associations between performance on inhibitory control tasks and counterintuitive reasoning tasks in maths and science in primary, secondary and higher education students, and even in adults (Babai et al., 2012; Brookman-Byrne et al., 2018; Coulanges et al., 2021; Khng & Lee, 2009; see Mason & Zaccoletti, 2021 for a review in science conceptual learning). Neuroimaging evidence points to the brain bases of these processes. Functional magnetic resonance imaging (fMRI) studies have shown that when adult and adolescent "experts" reason about counterintuitive concepts, brain areas thought to be involved in inhibitory control (e.g., dorsolateral and ventrolateral prefrontal cortex and anterior cingulate cortex) show greater activation than they do in "novices" (Allaire-Duquette et al., 2019; Allaire-Duquette et al., 2021; Brault Foisy et al., 2015; Masson et al., 2014; Potvin et al., 2020). Importantly, similar neural activation is observed when adolescents reason about science and maths counterintuitive problems and when they complete inhibitory control tasks (such as naming ink colours that colour words are written when the colour is incongruent, e.g., responding 'black' when presented with the word WHITE; see Dumontheil et al., 2022, for discussion).

From this scientific understanding of brain mechanisms, it was hypothesised that training inhibitory control may improve a learner's capabilities in science and maths. Crucially, however, neuroscience principles indicate that the inhibitory control processes are specific to content. There is no point making a child engage in some abstract brain-training games (such as naming the ink of colour words) and hoping that maths and science skills will improve. Indeed, this lack of 'far transfer' from cognitive training to broader educational abilities is a core finding of the Science of Learning (see, e.g., Sala et al., 2019). Instead, the control processes must be trained whilst embedded in the relevant content, in this case, while solving counter-intuitive science and maths problems appropriate to the age of the child.

To test this proposal, the computerised learning intervention "Stop & Think" was designed to make children aware of the existence of counterintuitive concepts and to train children to use their inhibitory control skills to delay their response, in order to successfully solve counterintuitive problems. This delay was important, as previous research had suggested that simply by imposing a delay on responding, children performed better in tasks requiring cognitive control (Diamond et al., 2002). Similarly, in adults, a warning about potential pitfalls in reasoning (as opposed to just giving the correct answer as feedback) improved performance in logical reasoning tasks (Houdé, 2000). Therefore, in the Stop & Think intervention, learners were presented with counterintuitive problems, and encouraged to delay their response before answering the question. If incorrect answers were given, a cycle of delaying and being shown potential correct reasoning was promoted rather than simply giving answers, in order to promote the inhibition of fast intuitive responses at the strategy level.

To establish the feasibility of the technique, a small-scale study in the UK was first conducted on 456 Year 3 (age 7–8-year-old) and Year 5 (9–10-year-old) children. The intervention was presented for 12 minutes at the start of children's normal science or maths class, three times a week, for 10 weeks. Children were either assigned to the intervention group, which was split into two modes of delivery – group-based and teacher-led, or individual and pupil-led – or to a teaching-as-usual control group. This pilot intervention demonstrated positive near-transfer effects in Year 3 children; the intervention group showed an improvement in counterintuitive reasoning skills, as measured by a 20-item assessment comprising of 10 maths and 10 science counterintuitive problems based on the content from the National Curriculum for England (Department for Education, 2013a, 2013b). Relative to controls, the Year 3 intervention group also showed far transfer to an increase in science attainment, measured by a standardised assessment: the Progress Test in Science 8. However, no intervention effects were observed in maths achievement, nor in Year 5 children. Finally this pilot study suggested that the interventions worked best when delivered by teachers, as opposed to being individual-led, likely due to the impracticality of repeatedly setting up the children on individual computers in each science/maths lesson (Wilkinson et al., 2020).

Following the pilot trial, and incorporating teacher feedback, the intervention was scaled up and introduced to 89 schools in the UK, reaching a total of 6,672 students. Once more, “Stop & Think” was implemented by teachers for 10 weeks, 3 times per week. Children were either assigned to the teacher-led intervention group, an active control group or a “teaching as usual” group. Results from this randomised controlled trial showed that the children in the intervention group experienced an additional two months’ progress in science learning compared to controls. Maths outcome measures were also accelerated by one month, although this did not reach statistical significance (Roy et al., 2019). These were promising results considering that the intervention was only run for 10 weeks, and the intervention was assessed based on far-transfer to educational tests. Furthermore, the cost of the “Stop & Think” intervention was £6 per pupil per year, over 3 years, resulting in a low implementation cost rating from the EEF (https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/learning-counterintuitive-concepts). This rating, used to determine the cost effectiveness of an intervention, is an important factor for school policymakers when deciding whether to implement an intervention.

This indeed highlights a divergence between researchers, who may be more inclined to prioritise the effectiveness or implementation practicality of an intervention, and policymakers, who may be more inclined to focus on factors such as cost. In turn, this divergence can lead to disagreements in which interventions to implement in schools and to take forward in the research process. There is not necessarily a direct mapping between evidence base and implementation in schools.

The case study illustrates other important features of developing and evaluating interventions in the science of learning. First, for the Science of Learning to accumulate a reliable evidence base, it is important that *evaluations are rigorous and robust*. For example, it has been shown that when researchers evaluate their own interventions, effect sizes tend to be larger, and studies are less likely to replicate (Wolf et al., 2020). The outcomes of "Stop & Think", as with all EEF intervention trials, were therefore analysed by independent evaluators. Second, to stand a chance of successful uptake in the classroom, interventions must involve *a dialogue with teachers*. "Stop & Think" went through several rounds of teacher feedback to refine the learning activity, to ensure it was optimised for implementation in the classroom. Third, an evaluation of the intervention under ideal conditions (a so-called efficacy trial) must be followed by *an evaluation of the intervention under more realistic classroom conditions* without the involvement of researchers (a so-called effectiveness trial). The latest iteration of "Stop & Think" is currently undergoing an effectiveness trial to test its utility and scalability under everyday conditions. This trial will be implemented for Year 3 and Year 5 (8- and 10-year-old) children across 175 UK schools, the results of which are pending.

Lastly, researchers must return to establish *whether an intervention is acting via supposed mechanisms*. For Unlocke, this basic research is also currently underway. A sub-sample of children taking part in the efficacy trial were assessed using behavioural tasks, including assessments of verbal and visuospatial working memory, inhibitory control, non-verbal intelligence, and counterintuitive reasoning, before and after training (Dumontheil et al., 2023). Cross-sectional associations between counterintuitive reasoning and executive function skills were found in Year 5 children, with evidence of a specific role of verbal working memory. The intervention benefited counterintuitive reasoning in Year 3 children only and executive functioning measures were not found to predict which children would most benefit from the intervention. Combined with previous research, these results suggest that individual differences in executive functions play a lesser role in counterintuitive reasoning in younger children, while older children show a greater association between executive functions and counterintuitive reasoning.

An even more restricted sub-set of children from the trial (n=56) were invited to take part in Magnetic Resonance Imaging (MRI scans) pre- and post-intervention, to determine whether any structural and/or functional brain differences resulted from the intervention. Analysis from this work is also pending, but preliminary results suggest no overall changes in brain structure or function. This is likely due to the small sample size and the short time frame in which the intervention was carried out and speaks to the practicality of using MRI methods with young participants, which is compromised by factors as participant drop out and poor signal due to head motion. An exploration of possible similarities in brain activation when carrying out counterintuitive reasoning and inhibitory control tasks using UnLocke data is also being undertaken (Palmer et al., in preparation), which may shed light on whether shared neural pathways are engaged for both types of tasks within the targeted intervention sample, that is, whether the findings of the broader scientific literature were replicated in these children.

How the case study illustrates the challenges of evaluations in Science of Learning

Transitioning from basic cognitive neuroscience to intervention is not always smooth sailing. By its nature, the UnLocke project involved cognitive neuroscientists, educators, psychologists, and independent evaluators, each with their own perspectives and priorities. This section discusses four major challenges which arose as part of the project, as well as a discussion of compromises made, and lessons learnt.

The first challenge was the selection of control groups. On one hand, policy makers preferred to include a teaching-as-usual control group, because their priority was to determine simply whether the intervention was superior to current practice. On the other hand, the cognitive neuroscientists were keen to include an active control group, that is, a group which completes a similar task to the intervention group, but the task differs in the element that is believed to be making the difference. This would ensure that any benefits were due to the specific intervention and not due to a placebo effect, whereby classroom performance can be raised simply by the novelty of participating in a new educational activity (an effect unlikely to be sustained). Both teaching-as-usual and active controls are valid control groups but provide different information: one answers does it work at all, the other does it work for the reason the designers think it does. To include both control groups increases the cost of a large-scale intervention. In this case, the decision was made to include both teaching-as-usual and active control groups despite the cost, because the project had both educational and research aims. In the "Stop & Think" study, the active control consisted of a similar computer assisted learning game which included content from the Personal, Social and Health Education (PSHE) curriculum. This activity had the goal of improving socioemotional skills, with no expectation that it would transfer to counterintuitive reasoning in science and maths (which proved to be the case).

The second challenge involved the practicalities of training teachers to use the intervention. In an ideal world, extensive training of teachers would be preferred to ensure the intervention was delivered in a consistent, reliable way (referred to as 'fidelity'). But with the high demands placed on educators, a compromise between training time and rigour is needed. In the efficacy trial, the researchers were involved in training teachers to ensure optimal delivery of the intervention, whereas in the subsequent effectiveness trial, researchers were not involved, and training took place via standardised written and video tutorials. The contrast between these two methods highlights the tension between idealised, research-based interventions, and the vagaries of classroom practice, while also placing a spotlight on the robustness of prescribed techniques to variable implementation. Only those that survive variable implementation across contexts are likely to be adopted by educators in the long-term.

The third challenge was the timing of the intervention. In terms of dosage, the activities (both intervention and active control) in the “Stop & Think” study were implemented for 10-15 minutes as part of standard science and maths lessons, creating a minimal additional workload for educators and requiring no additional learning time for students. This is arguably the most practical approach to introducing an intervention into schools, due to the already jam-packed school timetable. In essence, the intervention helped teachers by providing a lesson plan for a section of their lesson, helpful so long as it could be integrated with the rest of the lesson’s activities. In terms of duration, from a scientific perspective, the intervention would ideally be implemented consistently without breaks, but this is impractical should an intervention need to span multiple terms and school holidays. Each school is different, and some schools may run classes or revision sessions during holidays (especially for secondary school students who are completing exams), whereas others may actively discourage interventions taking place during certain times of the year (for example if exams are taking place during this time). Resolution requires the inclusion of educators in the design process, to ensure the smooth implementation of the intervention in the classroom and consistency with each schools’ timetable and priorities.

The final challenge is the importance of understanding mechanism. For some disciplines, knowing that an intervention demonstrates impact is enough. For example, the exact mechanisms of general anaesthetics are not currently known despite ongoing research, however, this does not discourage use of anaesthetics during surgery. Likewise, if an educational intervention appears to work, policymakers and educators may be content with this outcome and less concerned about mechanisms. However, understanding the mechanisms of action is important to make interventions more efficient and to understand the conditions in which they are likely to succeed and when they are likely to fail. Many researchers feel that understanding mechanisms of action can allow for personalised approaches and improve the effectiveness of interventions, by gaining a greater understanding of which element is making the changes (as do many medical researchers continuing to explore the mechanisms of general anaesthetics). Each student is an individual, and indeed, every teacher has a style of their own, and each classroom and school has its own unique context. Understanding mechanisms should, in theory, provide a way to overcome these differences and effectively transfer and scale the intervention across contexts and populations – if the most crucial elements are in place in each instance, change should occur as a result. Nevertheless, it is not always straightforward to gain a clear understanding of mechanisms given practical constraints on sample sizes for follow-up studies, and the utility of neuroscience methods such as MRI with younger children.

This case study has demonstrated the complexity of journeying from basic science to classroom intervention, and the various challenges and subsequent solutions of running an interdisciplinary project within the field of the science of learning. Bridging interdisciplinary divides can pose problems due to different priorities from each stakeholder. However, the benefits of running these types of projects, in terms of field progression, knowledge acquired and impact in the classroom, far outweighs the challenges. Furthermore, as the field progresses and collaboration continues, navigating differences in perspectives will become easier and provide better outcomes from all involved.

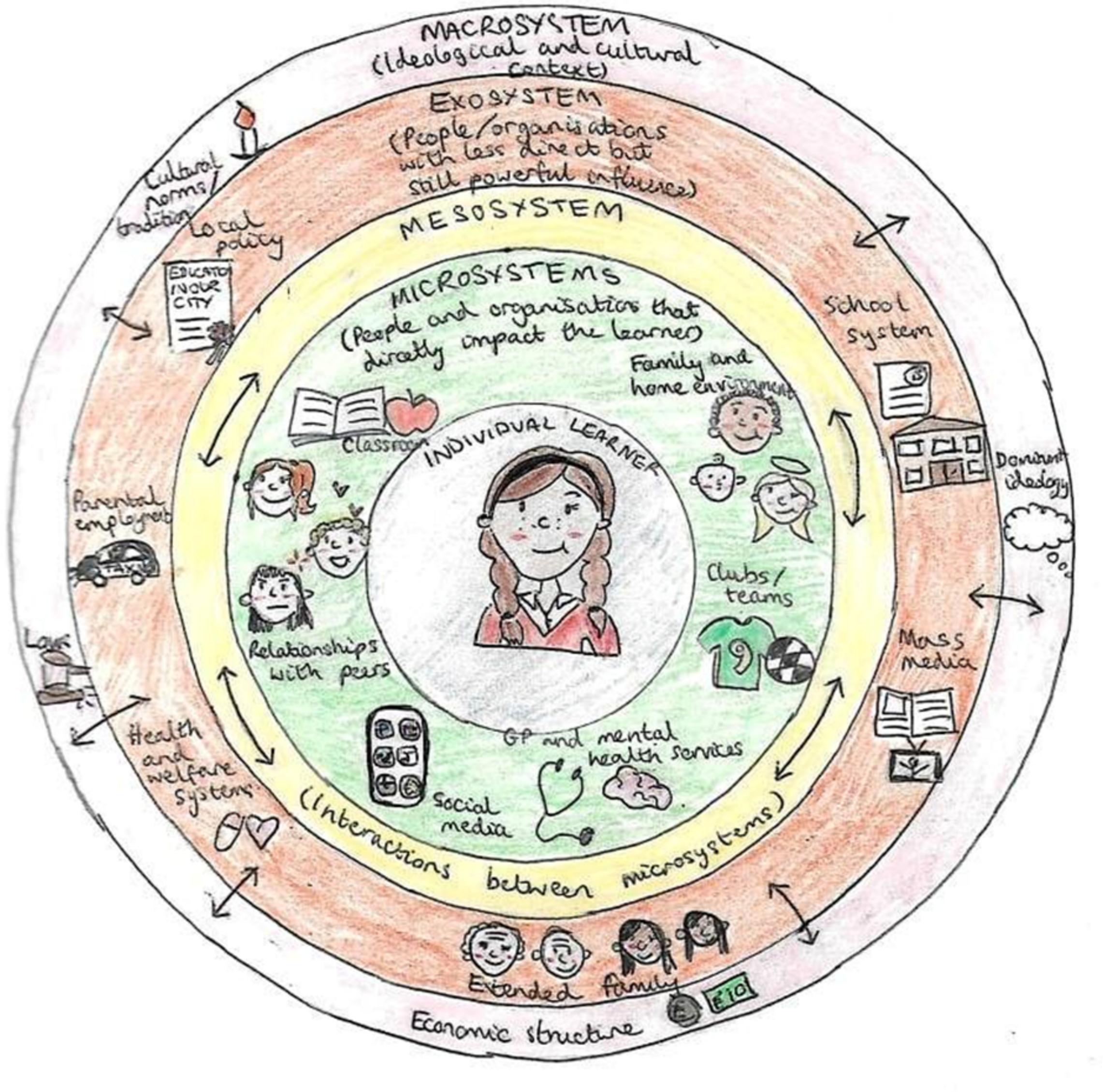
This section has described the field of the science of learning predominantly from a classroom-based perspective. However, classroom-based learning is only a small part of the learning process and there are many more factors involved in influencing learning outcomes. We now move to more holistic approaches.

Learning outcomes and the Whole Child in Context

When we think about learning, our minds may instinctively bring up images of structured educational environments like schools. However, children do not learn in isolation. Family, cultural, and environmental factors can have a significant influence on learning both inside and outside of the classroom. Children actually only spend around 10% of their waking hours in the classroom (OECD, 2021), so there is extensive time for factors external to the school environment to impact on learning. Within the Science of Learning, Bronfenbrenner's (2005) Ecological Systems Theory provides a useful, well-established framework to think about how factors in the child's life jointly contribute to their learning outcomes (Thomas et al., 2019). The framework considers the proximity of different influences for the child and distinguishes between factors that directly influence them (e.g., family, school, peers) and more distant systems (e.g., education policy) which will have indirect effects via the systems that are closer in proximity to the child (see Figure 2). This offers a neat way to help us think about the complexity of the environments in which children learn. It also highlights the importance of identifying at which level to intervene to improve learning outcomes.

Figure 2.

Ecological systems theory diagram adapted to the modern context



To give an example, we can apply this kind of approach to understand the recent changes to high school start times in California. At the individual level, we know that good quality sleep is important for learning and retention (e.g., Uji & Tamaki, 2023), but changes in the brain (including the circadian system) that occur during adolescence mean that teenagers do not get to sleep or wake up as early as children (Colrain & Baker, 2011). Good sleep hygiene and family routine around bedtimes will do little to help with tiredness when biology makes it hard to fit in the recommended amount of sleep and be up in time for school start times. To address this problem, change was needed at the macrosystems level (state governing board) to push back the school start time. Based on multiple studies showing that delayed school start times improve sleep and learning outcomes (Alfonsi et al., 2020; de Araújo et al., 2022; Lewin et al., 2017), it has been ruled that high schools cannot start before 8:30 a.m. (California Legislative Council, 2019).

Yet, in a connected world, wider economic and social barriers mean that later school start times are not a silver bullet for adolescent sleep deprivation. Some of the barriers to implementing this change outside of the narrow learning context include: childcare and transport challenges for families with multiple children of different ages; the economic impact of staggered opening times requiring for example that school buildings be kept open for longer (energy costs, estates staff); the need for teachers to be onsite longer or travel at different times (and consequent impact on their own family life); and the inflexibility of teacher contracts. Therefore, to succeed, even seemingly straightforward interventions to improve learning outcomes based on Science of Learning principles require an awareness of and engagement with the wider system in which pupils learn.

Whilst some factors such as sleep deprivation due to developmental changes are likely to influence all adolescents in a similar way, some risk or protective factors vary more from individual to individual. Children who frequently arrive at school hungry and anxious are likely to find it more difficult to recruit the attentional resources necessary to engage in their lessons than their peers. A good deal of research shows that children who grow up in unstable, poorer families struggle more academically and that these attainment inequalities might be explained by differences in the way their brains and cognitive systems develop (see Johnson et al., 2016, for a review). Families and cultural contexts are also thought to influence attitudes toward education and thus learning outcomes (Guay, 2016).

Since learning does not stop at the end of the school day, the way that extra-curricular time is spent may also be a driver of individual differences in learning outcomes. Some children have more access to learning opportunities outside of the classroom in the home (e.g., books, access to the internet, through interaction with their parents) and via community facilities (e.g., after-school clubs, museums, tutoring). This may partly explain how factors such as urban versus rural living (OECD Publishing, 2017), socioeconomic status (Broer et al., 2019), and parental working patterns (Vincent & Neis, 2011) predict pupil attainment.

However, unfortunately, factors which put children at risk for reduced or poorer learning opportunities tend to co-occur and compound academic difficulties. This means that it is often necessary to intervene on multiple systems to substantially improve learning outcomes. Indeed, it has been said that in education research we live in "a small effects world" where large differences in educational achievement of environmental origin arise from an accumulation of many small effects (e.g., von Stumm & d'Apice, 2022). That said, in some rarer cases, an individual risk factor can represent such a strong constraint on learning that it is considered a limiting factor. These have such a large influence on learning that intervening on other risk factors will have little effect on learning outcomes. For example, there is evidence that while socioeconomic status correlates with vocabulary development in typically developing children, it does not influence vocabulary in pupils with Down syndrome because the genetic mutation is a much stronger influence on word learning (Thomas et al., 2020).

Understanding the child as a whole thus presents an important challenge for researchers who wish to understand and make generalisations about factors affecting learning outcomes. The key question is what learning and teaching methods work best for which children and in which contexts – it is a story of contextual variation. To study wider factors related to learning outcomes which operate (and potentially interact) at different levels, researchers often turn to large cohort studies. In the section below, we describe an example of ongoing research at the Centre for Educational Neuroscience which makes use of data from a large longitudinal cohort study of adolescents.

Case study 2: diverse factors influence cognitive development and educational attainment in a longitudinal cohort study of teenagers (SCAMP)

Individual differences in executive function skills have been identified as important predictors of attainment in literacy and mathematics assessments (see Cortés Pascual et al., 2019; Spiegel et al., 2021, for reviews). Research in this area has predominantly focused on white, high socioeconomic status, neurotypical pupils from the United States. However, it is frequently pupils with executive function difficulties who are the intended beneficiaries of executive function interventions to improve educational outcomes. The mismatch between study participants and intervention recipients raises questions about the universality of associations between executive function and attainment.

Relatedly, only a handful of studies have looked at this association in adolescents, despite secondary school attainment having important consequences for job prospects and access to higher education. Of the few studies that do focus on adolescents, most are cross-sectional, so cannot tell us about possible directions of influence. For example, good executive skills might lead to better skills in mathematics, but equally, learning better maths skills might lead to superior executive function skills. In a cross-sectional study, these possibilities cannot be distinguished because any correlation between executive functions and maths skills is observed only at a single time point. Longitudinal research, where pupils are studied at multiple points in time, is needed to distinguish between these possible causal pathways. At the same time, most studies of adolescents do not account for important background characteristics of pupils which are correlated with both executive function and attainment (see Jacob & Parkinson, 2015, for an in-depth discussion of this issue). Without controlling for these factors, we cannot rule out the possibility that the associations we see between executive function and school attainment are actually associations between some unmeasured characteristic (e.g., socioeconomic status) and attainment.

The evidence base surrounding factors in teenagers' lives that might affect their executive function skills and therefore their school outcomes is also limited. Risky health behaviours such as drinking alcohol, smoking and using drugs often onset during adolescence and cross-sectional evidence shows that pupils who engage in these behaviours score lower on measures of education-relevant cognitive abilities (e.g., Jadhav & Boutrel, 2019; Lisdahl et al., 2013). There is also evidence linking video game play and social media use to cognitive abilities (see Alho et al., 2022; Levine et al., 2012 for reviews). But again, there is an ambiguity: which comes first, executive function or **insert target behaviour here**?

Of course, to address such gaps in the knowledge regarding executive function and attainment demands a huge amount of information on a very large number of secondary school pupils, from the tens or hundreds of participants involved in experimental studies to the thousands required in representative cohort studies. As with other types of research in the Science of Learning, such an enterprise depends upon input from researchers with varied expertise. Hence, developmental psychology and neuroscience researchers at the Centre for Educational Neuroscience collaborated with epidemiology and biostatistics researchers from Imperial College London's School of Public Health to shed light on outstanding questions about associations between executive function and attainment. To do this, researchers analysed data from the Study of Cognition, Adolescents and Mobile Phones (SCAMP; Toledano et al., 2018), a large longitudinal cohort study of adolescents from the Greater London Area involving over 6,000 pupils, hosted at Imperial College London. This large-scale study was made possible by funding from the Department for Health and Social Care and the Medical Research Council and was originally designed to explore the effects of mobile phone usage on adolescents' cognitive abilities, physical and mental health.

The adolescents participated in computerised cognitive testing and answered a series of questionnaires at age 11-12 and again at age 13-15. For all participants, data were collected for their results on the national standardised assessments which take place at the end of primary school (age 11; maths, science, reading and writing Standard Assessment Tests [SATs]) and the end of secondary education (age 16; maths, science, and English GCSEs) from the UK Department for Education's National Pupil Database. The ongoing projects using SCAMP data to better understand the relationship between executive function and attainment include investigations of the role of socioeconomic status, neurodivergence, mobile phone use, health behaviours and multilingualism in modulating or mediating observed associations between cognitive abilities and later educational achievement.

This type of large-scale longitudinal study helps to identify reliable patterns of relationships between individual characteristics and learning. Studying pupils over time also allows us to understand the directionality of associations, increasing confidence about which relationships are causal and therefore better targets for intervention to improve outcomes. Basic science research is then needed to unpack the associations and show us what is important and manipulable about the broad factors we study. For example, in the SCAMP cohort, one recent finding showed that parental occupation status is associated across adolescent development with working memory skills (Perry et al., in preparation). Some possible explanations for this include:

- Access to activities that could enhance working memory – parents with more prestigious jobs are more able to afford to pay the fees for activities such as music lessons, sports clubs, and tutoring.

- Stress – living in a low-income household is stressful due to resource scarcity and chronic stress, which influences the development of brain networks supporting executive function.
- Lifestyle factors – financially struggling households are more likely to be characterised by levels of household chaos, insufficient sleep, and nutritionally deficient diets, all of which have negative effects on cognitive development.
- Genetic similarity – working memory skills are somewhat heritable and a propensity to good working memory could be beneficial for working in a high-status job in the parent and performing well in a cognitive test in the child.

To disambiguate between these different possibilities and uncover the mechanism(s) explaining the relationship between parental occupation and working memory, we would need to pull together evidence from several different types of study. Intervention studies (where we take a group of pupils, change something in their environment holding all else constant and compare them to a group of similar pupils who did not receive the intervention on a working memory measure) could be used to test some of the explanations raised above. However, some things are impossible (e.g., genetics) or unethical (e.g., household chaos) to experimentally manipulate. To test such possible explanations instead requires genetically informed designs, and small scale quasi experimental studies where we define groups to compare on our working memory measure based on a naturally occurring characteristic such as level of household chaos.

These types of additional study are necessary if we are to understand how we can institute change to reduce social inequalities in adolescents' working memory abilities. More broadly, cross-disciplinary approaches making use of multiple different research methodologies are essential whenever we wish to study the complex, interconnected contexts in which individuals learn.

Bridging research, practice, and commercial interests

One of the goals of interdisciplinary research in the Science of Learning is to bring the abstract principles of learning into classroom settings, making findings relevant and useful for teachers in their practice. This topic has been the focus of conversation and debate in educational research for decades, along with the linked question of the purpose of research: should the ultimate goal of education-related research be the improvement of learning in real educational settings (as argued by Mortimore, 2004), or should the purpose of research be "confined to the advancement of knowledge" (Hammersley, 2003, p.13) without direct consideration for how its principles can be applied in real contexts?

The choice of research paradigm is not neutral in these debates. Experimental paradigms are typically used to investigate causal relationships. These paradigms often form the basis for interpreting 'what works', such as in the use of Randomised Controlled Trials for assessing the effectiveness of classroom interventions or approaches. Experimental paradigms typically have the goal of extracting broad generalisable principles from representative samples, with limited regard to the influence of context in application (Pawson & Tilley, 1997). By contrast, practitioners are typically interested in the specifics of what meets the needs of their particular students in their context, and how to directly address practical problems in their setting (Coldwell et al., 2017). In other words, practitioners want to engage with work that has direct relevance to their classroom practice (Gore & Gitlin, 2004). It may not be surprising, then, that when asked for their views on the relevance of research to their work, practitioners have mixed opinions. Whilst acknowledging that research evidence can be beneficial to their practice and expressing an interest in further training and knowledge support (YouGov, 2022), they also find that the kinds of questions researchers pose are often of too little practical relevance to their work (Vanderlinde & van Braak, 2010). The result is a kind of lingering ambiguity about whose responsibility it is to apply the general principles identified in research to individual contexts of educational application; and debate about what kinds of research design are appropriate for establishing effective practices, in furtherance of the goal of building an evidence base for education.

Participatory research methods can provide a way forward by building the voice and concerns of educators into the research model. However, when the questions posed by educators are stripped back and shaped by researchers to meet the needs of a testable, falsifiable hypothesis generation, this can also reduce the usefulness and applicability of findings. By the same token, without dialogue with researchers, questions that educators have about their everyday practice may not be formulated in a way that is readily answered by research.

Each of these challenges points to the reality that research into the science of learning is often not immediately useful – it requires *translation.* Prosaically, this may be in a literal sense, as practitioners find that the complexity of language and technical details of published research papers fosters a gap in understanding (Vanderlinde & van Braak, 2010). The practice of producing lay summaries for research papers may be a useful strategy to promote better integration of evidence through accessibility of findings. However, translation is also intended in the broader sense of cultivating systems to foster more effective science communication and researcher-practitioner dialogue. Within the United Kingdom, the EEF is an example of an organisation established to promote better use of evidence in education. Some of the organisation's key initiatives include establishing a network of research schools – a collaborative system through which educators can access professional development opportunities and engage in communication regarding best practice – and an online resource, the Teaching and Learning Toolkit, which provides accessible graphical summaries of the available evidence bases for educational interventions and approaches (Education Endowment Foundation, 2021). One recent instance of effective dialogue can be found in the EEF's report summarising cognitive science research relevant to the classroom (Perry et al., 2021); and in turn, the Chartered College of Teaching, the professional body for teachers in the UK, producing a report which identified teachers' priorities for future research in cognitive science in education (Müller & Cook, 2023).

In the United States, the Reading League is an example of a knowledge broker organisation aiming to improve the standards of evidence in practice for the development of literacy. Like the EEF, they do this through a range of initiative strategies, including direct training opportunities, conferences to foster partnerships and knowledge transmission, and producing their own accessible resources. Notably, rather than simply telling practitioners what they should or should not be doing, the focus of these resources is on empowering them to make the choices, based on best evidence, that work for them in their contexts. For example, their Curriculum Evaluation Guidelines resource advises practitioners on 'red flags' to watch out for that indicate a literacy programme may be following approaches that are not aligned with best evidence (The Reading League, 2023).

Despite progress, there is evidence that the integration of research evidence into practice remains generally poor, in the UK at least. This was reflected in a 2017 Department for Education report into the status of evidence-based practice in schools, which found that implementation of evidence fell short of expectations (Coldwell et al., 2017). One of the key reasons identified by the report was that educators generally felt underconfident in engaging with research, perhaps due to lack of professional development in the skills that would help them to access and integrate research evidence into practice. More recently, a survey of British schools identified that the majority of classroom interventions currently in use (67%, 92 of the 138 surveyed interventions) had no published evidence demonstrating efficacy (Pegram et al., 2022). While educators may be interested in research evidence, the evidence that they require is either not accessible to them, not well understood (at least, in an actionable form to influence decision-making), or does not address the questions and issues that they find important.

These are ongoing issues. The Centre for Educational Neuroscience in London is currently exploring some of the reasons for the continued challenges with bridging research and practice as part of a collaborative, international project with commercial educational intervention providers, to understand how and when evidence is useful to those providers in applied real-world contexts. Preliminary analysis (Bowen et al., in preparation) suggests that the chief barriers to implementing evidence in education include basic accessibility issues: research is costly and extremely time-consuming to conduct, and the pace at which outputs are produced and disseminated is glacial by modern industry standards. Communication between researchers and practitioners is also a central concern – not only in terms of making findings accessible and useful, but in the more fundamental terms of establishing a common understanding regarding the meaning and appropriateness of evidence. For example, large-scale randomised controlled trials seek to average out the effects of the varied contexts of education to focus on the effects of a given method across all children. Yet to the educator, the essence of teaching and learning may be its dependence on contextual factors. There is a clear tension which merits exploration through engaging with practitioners and other stakeholders in education. This we consider in the case study below.

Case study 3: Evolve, a social impact company

Evolve is a UK-based social impact company founded in 2003, which aims to improve the physical health, mental health and life prospects for children who are struggling at school

(Evolve, 2022). It also works with gifted and talented children to maximise their potential. Evolve's flagship programme, Project HE:RO (Health Engagement: Real Outcomes) is a school-based child-centred intervention which takes a long-term and holistic view of the well-being and development of the child: the intervention involves a trained health mentor delivering daily support for potentially the entire academic year through a combination of activities, including classroom-based learning support, physical education, diet and health education, and group and individual mentoring sessions. Through this combination of activities, the intervention aims to directly address issues the child may be facing across cognitive, physical, and emotional domains.

Having conducted prior qualitative research projects and a small-scale quasi-experimental trial (The Health Foundation, 2020), Evolve set up a collaboration with the Centre for Educational Neuroscience to pursue a scaled-up evaluation of intervention effectiveness. This led to a partnership being established through a PhD project co-funded by the UK Economic and Social Research Council. The project employed a mixed-methods approach combining a longitudinal quasi-experimental cohort study with qualitative analyses.

Findings from the ongoing project illustrate the challenges of evaluating holistic interventions in school settings, and of broaching the divide between commercial education providers and researchers. The school setting as a research environment imposed practical challenges. There were everyday limitations on data collection, from the amount of data that could be collected, to the types of data collection that could occur, and when the data collection could happen. Data collection occurred primarily on a large-scale class-wide basis, which sometimes introduced data reliability issues: cognitive testing and surveys were not conducted under controlled conditions. Data on outcomes of practical relevance, such as reductions in behavioural incidents, proved difficult to gather: school systems did not have consistent ways of tracking behavioural incidents, while teachers could not consistently track behavioural incidents in their classroom at the level of detail required for a meaningful analysis. Where data collection was missed or went awry for any reason (including technical difficulties such as internet bandwidth problems or equipment failure), there was little opportunity for repair. Data loss in this case study, from a combination of collection issues, student absences, and unusual circumstances such as school closures due to Covid and extreme weather, meant the statistical power of analyses was comprised at the end of the first year of the collaboration, despite best intentions and efforts from all stakeholders.

For Evolve, one of the chief challenges was integrating the requirements of the research project alongside running their usual business and intervention practices. As the schools involved were their paying clients, it was difficult to ask schools to fulfil the additional data needs of the project, as these needs placed more demands on teacher and administrator time. Since the schools did not benefit directly from involvement in the research project, there was no incentive to provide the additional support and resources that would help it to succeed. Indeed, there were fears from the intervention provider that should the research study yield null findings, which could simply arise from data quality issues or insufficiently sensitive outcome measures, the null finding would undermine the provider's business model – despite a generally positive view of the intervention outcomes from both schools and the provider. Qualitative evaluation went on to explore and elucidate the perceived benefits of the intervention and optimal conditions for implementation, overcoming some of the limitations in the quantitative arm of the evaluation which hobbled the ability to form conclusions.

The collaboration with Evolve has also succeeded in advancing understanding of how researchers and educational practitioners can better work alongside each other. Clear, accessible, and timely communication proved key elements to foster success in the collaboration, as well as mutual understanding and the establishment of shared goals between each of the stakeholders in the project. It was necessary to be clear on which elements of the study were crucial to its success, and which were less essential. From the researcher's perspective, the ability to anticipate potential issues and establish a timely dialogue on ways to mitigate their effects on the final outputs proved to be a key skill, which required a solid understanding of how classroom settings operate. Such knowledge is not readily acquired in the laboratory alone.

In the project to date, some key findings include the need for researchers to be flexible with methods to meet the adaptive needs of educational settings. Where quantitative data proved difficult to collect, qualitative data provided a means of plugging the gap, as well as a way of more richly examining intervention processes and unpicking the mechanisms behind impact. Qualitatively informed variables included mentor expertise and overall intervention quality within individual schools, which integrated observational fieldwork data with inter-rater agreement on a categorical rating scale. To return to the initial question of whether research should aim to directly inform practice, this case study suggests the following: while existing research approaches may be better suited to informing theoretical understanding, it is likely that educational providers will continue to look to research as a means of establishing or discounting effectiveness. Therefore, questions of how to progress methodologies in the Science of Learning, and how far researchers are willing and able to adapt existing models to make their findings relevant, are key to future progress. Can we develop a new and progressive model of evidence generation that satisfies everyone?

General discussion: Challenges for research methodologies in interdisciplinary, translational research

The future of the Science of Learning relies on the accumulation of its evidence base and the pathways to implementation in the classroom. Methodological models are worth discussing in more depth to better understand the challenges to be overcome. Issues regarding how control groups are defined have already been mentioned earlier in this chapter, but whichever way controls are defined, the gold-standard of a randomised control condition is often impractical or impossible in educational research (see Worrall, 2007, for discussion). On a practical level, randomisation of participants to different conditions may be compromised by the specific characteristics of the population of interest, by ethical concerns with assigning students who may benefit from intervention to a control condition, or simply by the constraints of the school/classroom setting. The idea that it could be possible to hold everything constant except for one experimentally manipulated variable is perhaps the concept that is most inconsistent with classroom reality. Therefore, the conventional experimental model used to establish causation (pre-post comparisons between intervention and control conditions) is disrupted.

In lieu of extending the kind of experimental control available in the research lab to the classroom, an alternative is to embrace the variability and inherent messiness of the context and incorporate it into the trial. Identifying and measuring extraneous variables which can then be factored in as covariates in regression models and examining effects on sub-groups of the overall sample population can allow for a more nuanced understanding of what works, for whom, and why within the context of the traditional pre-post model. An implication of this approach is that larger sample sizes are required to accommodate the greater number of variables.

It would be a mistake, however, to suggest that methodologically, there is only one way forward for the field. Robust, large-scale experimental or quasi-experimental trials have their place, but well-designed and applied single-case studies can be informative for establishing effects on individuals, particularly in cases where the population of interest is small or difficult to access, as is often the case in special education research. New methodological standards to progress the field in this area have recently been proposed

(Ledford et al., 2023). In addition, mixed-methods research should be increasingly incorporated: qualitative methods are not only useful for generating rich, ecologically valid data, but triangulating qualitative and quantitative findings can increase the usefulness and relevance of findings for policymakers and practitioners (Frost & Nolas, 2013; Nutley et al., 2007; Rogers et al., 2023).

In addition to progressing methodologies, the Science of Learning would benefit from greater integration of practitioner experience and viewpoints. At present, the flow of information between researchers and educators is often one-way (*from* researchers *to* practitioners) and occurs late in the research cycle (at the dissemination stage, rather than planning and execution). Whilst outreach initiatives – such as the seminar series and blogs for teachers produced by the Centre for Educational Neuroscience[1] – are valuable in generating interest in the Science of Learning, teacher input from the outset would help guide researchers towards generating evidence that is usable within the school context. To some extent, teachers are the experts on what will and won't work in their classrooms. Yet their expertise is not always crystallised in a way that can accumulate or be generalised. While researchers are sometimes out of touch with the realities of the classroom, teachers can be naive to research methods, that is, how evidence can realistically be employed to understand what is effective. While neither needs to become an expert in the others' field, they need to engage in a dialogue. However, this requires explicit recognition and structures put in place to support it. Translational fields may flicker into existence by chance or happenstance, but

[1] What we know about the learning brain: http://www.educationalneuroscience.org.uk/resources/what-we-know-about-the-learning-brain/; How the brain works: http://www.educationalneuroscience.org.uk/how-the-brain-works/; Special Education Needs evidence base: http://www.educationalneuroscience.org.uk/neurosense-resources/; Neuromyths: http://www.educationalneuroscience.org.uk/resources/neuromyth-or-neurofact/; What works in my classroom: http://www.educationalneuroscience.org.uk/resources/what-works-in-my-classroom/; What educators say about educational neuroscience: http://www.educationalneuroscience.org.uk/what-educators-say/

they will only prosper with investment in the infrastructure to support the necessary dialogues.

A look to the future of the Science of Learning

The Science of Learning looks to support education and improve learning outcomes across the lifetime, but the field must continually adapt in line with changes in technology, culture, and employment landscape. The progression of the field thus relies on multidirectional communication between researchers, educators, policymakers, and stakeholders, leading to a better understanding of each parties' priorities, for successful and productive research to be translated to the classroom.

Fortunately, the integration of evidence into school practice is growing, spearheaded by numerous initiatives including the Education Endowment Foundation in the UK and, on a global level, the UNESCO International Science and Evidence Based Education Assessment (ISEEA) (https://mgiep.unesco.org/iseeareport). The ISEEA is the result of an initiative of the UNESCO Mahatma Gandhi Institute of Education for Peace and Sustainable Development (MGIEP). Launched in March 2022, it brings together multidisciplinary expertise on educational systems to determine how knowledge, education and learning need to be reimagined in a world of increasing complexity and uncertainty, to provide an evidence-based assessments to inform educational policy making.

The ISEEA aims to pool together vast amounts of information and data regarding all aspects of education in order to answer urgent and important questions surrounding current education systems around the world, such as:

1. Is the current education system serving the right purpose?
2. Is the current education system supporting learners in facing contemporary challenges and meeting societal needs?
3. How can research be used to improve the educational system?

4. How should data be used in educational policymaking?

The findings from this assessment emphasise the vital role both cognition and emotion play in learning and stress than a one-size fits all approach to learning is not effective because it benefits some students over others. Personalised learning, therefore, is likely the way forward, and research to understand how context and social factors mediate cognitive abilities is a step towards making this a reality.

Progression of any field is dependent on a clear objective. The Science of Learning strives to improve learning outcomes across the lifetime, while promoting human well-being. Yet, a crucial query remains: what do we specifically mean by improving learning outcomes? This is arguably one of the most important and delicate question for the field. Should the field focus on bridging the gap between low and high achievers, or should the goal be to raise educational outcomes across the entire population? Should we be directing our efforts towards aiding those with special educational needs or does inclusivity extend to all individuals? Who is the priority? While these questions are undoubtably daunting, they demand a consensus to progress the field in the right direction. We hope that the increasingly collaborative nature of the field, alongside initiatives such as the ISEEA, will provide a platform for experts to come together to work towards answering some of these questions.

Whilst much of the discussion in this chapter has concerned interactions with educational practitioners and providers, understanding the roles of other stakeholders can also provide insight on the root causes of existing challenges and shed light on potential solutions for the future of the Science of Learning. A recent interdisciplinary international conference, organised jointly by the Centre for Educational Neuroscience and the Laboratory for the Psychology of Child Development and Education (LaPsyDÉ) and hosted by Université Paris Cité, explicitly aimed to examine the interactions between multiple stakeholders, including policymakers, funders, school leaders and research institutions (Bowen et al., submitted for publication). Key findings from this event concerned the challenges related to the methodologies currently available to evaluate what works, how findings are communicated and how evidence is used by stakeholders and policy makers. For example, at a methodological level, one-off trials on tightly defined outcomes can give a misleading impression of 'what works' to policymakers, and thus the need for longer-term, multidisciplinary and multi-method research projects was emphasised. Moreover, there is a need for greater evidence accumulation to ensure that the findings policymakers are basing their decisions on reflect a true consensus of the field. Indeed, evidence accumulation is a necessity for improving evidence integration into education, as there is a risk that communicating uncertainty (which commonly is a marker of best practice in research circles) can undermine confidence in science amongst stakeholders and muddy the waters, thereby preventing clear and well-informed decision-making. Lastly, at an over-arching level, if funding provision were available for initiatives which improve translational infrastructure, rather than just basic science and evaluations of new educational methods, it would open the doors to meaningfully advance the field by providing fresh avenues to promote interdisciplinary communication and access to research by all stakeholders.

Conclusion

In this chapter we provided an overview of the diversity of research undertaken in the Science of Learning. We gave examples from neuroimaging research, big data studies, and qualitative interviews (to name but a few methods) focusing on topics as varied as investigating the cognitive skills used when answering specific types of maths and science problems, to exploring the relationship between socioeconomic status and cognitive skills in teenagers, to understanding the benefits of a multi-pronged, child-centred health mentoring intervention.

We first took you on a journey from basic research to classroom-based intervention, using the "UnLocke" project as a case study. We guided you through one model of creating and scaling up interventions, beginning with goal identification, followed by lab-based feasibility studies, then classroom-based pilot studies, efficacy trials and finally effectiveness trials. Key challenges in the translation of research into usable classroom intervention arising from the oftentimes differing needs and priorities of researchers and practitioners were discussed.

We then highlighted the complexity of studying learning processes, given that they do not occur in isolation from the complex and dynamic world we live in. Bronfenbrenner's Ecological Systems Theory was used as a model of the many inter-connected systems and processes that can help or hinder pupils' learning and as a way of thinking about what we can and should intervene on to improve learning outcomes. The many projects utilising data from the Study of Cognition, Adolescents and Mobile Phones were described and used to exemplify the benefits of large cohort studies, and the importance of understanding the learner in context.

Next, we extended the theme of learning in context to consider lessons learned from engaging in translational research with the social impact company, Evolve. Participatory methods and partnerships between research organisations and educational organisations are essential to promote dialogue, understand each other's purposes and work towards collaborative generation and integration of evidence; research must answer the questions that are important to stakeholders in ways that they can understand. We also highlighted that the unique challenges of educational settings for research can be addressed if researchers are aware of them and adopt a flexible methodological approach.

Finally, we looked to the future and shared our hopes for the future of the Science of Learning field. Teachers are clearly interested in evidence-informed practices and new initiatives – such as those from the EEF and ISEEA – promise to make the implementation of effective, high-quality interventions informed by Science of Learning research a reality in the not-so-distant future. Moreover, we have faith that ever evolving and growing transdisciplinary collaborations will enable the field to progress with a clearer idea of how to achieve its mission of more effective learning, better learning outcomes, and support for learners' health and wellbeing.

Acknowledgements

The UnLocke project was funded by jointly funded by the Wellcome Trust and the Education Endowment Foundation (grant number N—1343). LP's research was funded by a Birkbeck studentship scholarship. The SCAMP study is an independent research project funded by the National Institute for Health Research (NIHR) Policy Research Program (PRP; Secondary School Cohort Study of Mobile Phone Use and Neurocognitive and Behavioural Outcomes/091/0212) via the Research Initiative on Health and Mobile Telecommunications – a partnership between public funders and the mobile phone industry. This study was supported by funds from the NIHR Health Protection Research Unit in Chemical and Radiation Threats and Hazards (Health Protection Research Units -2012-10141), a partnership between Public Health England and Imperial College London, and the MRC Centre for Environment and Health [MR/L01341X/1]. An extension to SCAMP was funded by the NIHR PRP. RP's research was funded by a Bloomsbury Colleges Studentship. AB's work with Evolve was supported by a co-funded PhD student with the UK Economic and Social Research Council awarded to Michael Thomas, Andrew Tolmie and Evolve (John Bishop).

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