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Innovating Pedagogy 2016

Exploring new forms of teaching, learning and assessment, to guide educators and policy makers

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Open University Innovation Report 5

A full-text PDF version of this report is available to download from **www.open.ac.uk/innovating**

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Page 9. Elements of a new science of learning. In Meltzoff, A.N., Kuhl, P.K., Movellan, J., Sejnowski, T.J. (2009). Foundations for a new science of learning. Science, 325(5938), 284-288. Image © Andrew Meltzoff. Reproduced with permission. [Photo credits: R. Goebel (neuroscience), iStockphoto.com/J. Bryson (education), Y. Tsuno/AFP/Getty Images (machine learning)].
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Executive summary

This series of reports explores new forms of teaching, learning and assessment for an interactive world, to guide teachers and policy makers in productive innovation. This fifth report proposes ten innovations that are already in currency but have not yet had a profound influence on education. To produce it, a group of academics at the Institute of Educational Technology in The Open University collaborated with researchers from the Learning Sciences Lab in the National Institute of Education, Singapore. We proposed a long list of new educational terms, theories, and practices. We then pared these down to ten that have the potential to provoke major shifts in educational practice, particularly in post-school education. Lastly, we drew on published and unpublished writings to compile the ten sketches of new pedagogies that might transform education. These are summarised below in an approximate order of immediacy and timescale to widespread implementation.

1 **Learning through social media:** Outside schools and colleges, people learn less formally. Some use social media such as Twitter and Facebook to share ideas and engage in conversations. These sites can offer a range of learning opportunities, to access expert advice, encounter challenges, defend opinions and amend ideas in the face of criticism. Unfortunately, the same sites may present learners with inaccurate information, biased comments and hostile responses. Some organisations have set up social media specifically to offer learning opportunities. Learners are helped to share experiences, make connections, and link these with teaching resources. Other educational sites are based on projects, such as ‘RealTimeWorldWarII’, ‘The Diary of Samuel Pepys’ and NASA’s ‘MarsCuriosity’ Twitter account. Educators on these sites have multiple roles that differ from those of a classroom teacher. These projects require expertise, as well as the time and ability to take on different roles. Anyone can engage and leave at any time, but a skilled facilitator who takes on the tasks of filtering resources and engaging people can keep a social media project running for many years.

2 **Productive failure:** Productive failure is a method of teaching that gives students complex problems to solve and attempt to form their own solutions before receiving direct instruction. The aim is for students, working together, to use their prior knowledge to consider possible solutions, then evaluate and explain the best answer. By struggling and sometimes failing to find a solution, the students gain a deeper understanding of the structure of the problem and its elements. After this process, their teacher explains the essential concepts and methods of the solution, helping students to consolidate their knowledge by comparing good and bad answers. Productive failure has been

investigated in 26 Singapore schools, and has been replicated by studies in the USA, Canada, Germany, and Australia. The pedagogy requires students to embrace challenge and uncertainty. They may feel unconfident at first, but this experience can help them become more creative and resilient. In order to implement learning with productive failure, teachers will need a deep understanding of the topic and may need to make fundamental changes to how they teach.

3 **Teachback:** As well as learning from teachers, we can learn by explaining to other people what we think we know. This is the basis of Teachback. One person (who may be a teacher, an expert, or another student) explains their knowledge of a topic to a learner. Then that learner attempts to explain, or teach back, what they have understood. This offers two benefits. It helps learners to understand a topic or problem by reframing it in their own terms. They also need to explain what they have learned in a way that is understandable. If the listener cannot make sense of the learner's explanation, then they discuss the topic until they understand each other. Teachback has been used in healthcare. Doctors and nurses can check that they have explained a treatment clearly by asking their patients to explain or demonstrate what they have been told. The method could be adopted more widely, for any topic where it is important to reach a shared understanding. However, if neither person is knowledgeable, the outcome could be shared misunderstanding.

4 **Design thinking:** Design thinking solves problems using the methods and thinking processes used by designers. These include creative processes such as experimenting, creating and prototyping models, soliciting feedback, and redesigning. Design thinking places learners in contexts that make them think like designers, creating innovative solutions that address people's needs. Learners need to solve technical problems but they also need to understand how users will feel when employing the solutions. Design thinking is a social as well as a mental process. It involves thinking and working across different perspectives and often involves conflict and negotiation. For example, students designing an educational computer game need to think from the perspective of a good teacher as well as from the perspective of a game player. As a pedagogy, design thinking may involve civic literacy, cultural awareness, critical and creative thinking, and technical skills. When implementing this approach in the classroom, the teacher and students need to take risks and try new methods.

5 **Learning from the crowd:** Appealing to the crowd gives access to valuable sources of knowledge and opinion. Amateurs and experts exchange ideas, generate and discuss content, solve problems, vote for the best solutions, and raise funds. A classic example of the crowd in action is Wikipedia, the online encyclopaedia co-created and continually updated by the public. Other examples include citizen science activities such as identifying birds and classifying galaxies. However, we are not yet using the wisdom of the crowd to its full potential as a resource in education and for learning. Possible applications of crowdsourcing in education include collecting and curating teaching resources, letting students share and discuss their work online, and providing opinions and data for use in projects and research studies. Crowdsourcing can lead to research that is initiated by the general public, rather than by scientists, and the opportunity to seek solutions to real-life problems. Designing and supporting such activities offers a way to scale them up. It also teaches the public to think scientifically, to appreciate sciences, and to support the work of scientists. Approaches need to consider the quality and validity of the contributions that are made by the public; the crowd may be wrong!

6 **Learning through video games:** Video games are powerful market and social forces. They can make learning fun, interactive, and stimulating. 'Lemonade Stand' was a 1970s computer game that engaged children in pricing, advertising, buying, and selling lemonade. From this promising beginning an industry has grown that includes serious games, gamification and game-infused learning. The focus can be on games designed for education, the use of game elements in workplace training, simulations such as flight trainers, or on social benefit. Players can try out unfamiliar roles and contexts and make consequential decisions, for example in simulated financial trading. However, it is difficult to balance learning with fun. A solution may lie in collaboration between professional game designers, software engineers, and learning experts. Together, these groups could develop game engines based on effective pedagogy, employing learning analytics to adapt game experiences to players' educational goals and actions.

7 **Formative analytics:** Most current applications of learning analytics aim to measure and predict the learning processes of students by tracing their behaviour and inferring their thinking processes. Analytics track, for example, time spent on online learning, or performance on an assessment. By identifying who may be at risk of failing a test, summative learning analytics provide teachers with a digest of performance and insight into who needs support. In contrast, formative analytics support learners to reflect on what they have learned, what can be improved, which goals can be achieved, and how they should move forward. By providing analytics for learning rather than analytics of learning, formative analytics have the potential to empower each learner through timely, personalised, and automated feedback, including visualisations of potential learning paths.

8 **Learning for the future:** Learners need to be educated not just for today but for the future. They should acquire skills and dispositions that will enable them to cope with an uncertain life and a complex work environment. Learning for the future builds human capacity to learn. The emphasis is not just on mastering content, but also on acquiring skills to learn, unlearn and relearn. These include the ability to change perspectives in the light of new information and understanding. This approach can help students to acquire critical thinking skills, gain social competencies related to learning and working together, and develop resourcefulness in learning. Future-ready learners have agency and autonomy in planning what and how to learn. They have the skills to be responsible citizens, contributors and innovators in an uncertain future. They also have mature cultural and interpersonal understanding.

9 **Translanguaging:** In a globalised world, many learners are studying in and speaking a language that is not their mother tongue. Translanguaging refers to moving flexibly and fluidly between languages. Pedagogical strategies engage the language abilities of bilingual students in teaching and learning, for example by using bilingual partners, organising international collaboration, searching the internet in multiple languages and accessing a wide range of online communities and resources. Translanguaging can expand and deepen students' understanding and help them to gain broader perspectives. It can also enrich the cultural experience and world views of other learners. But a bilingual classroom may exclude monolingual learners or take for granted the ability of bilinguals to use their languages for effective learning. Translanguaging might also encourage fusion of languages and threaten the survival of 'standard' languages (such as International English) that can facilitate access to education and build mutual comprehension between people from different cultural backgrounds.

10 Blockchain for learning: A blockchain stores digital events securely on every user's computer rather than in a central database. This is the technology behind digital currencies like Bitcoin. Blockchain learning explores how this approach could be applied to education, shifting from central records of student performance held by schools and universities to a more democratic model in which achievements are recorded by a wider range of participants. Blockchain technology allows any participant to add a new record such as an exam score to a single digital chain of events. This chain is stored across many computers, yet cannot be altered or undone. A blockchain could be used as a permanent shared record of intellectual achievement. It enables anybody to store academic certificates, creative works such as poems or artworks, even original ideas. There is no need for individuals to claim their inventions – the record is there for all to see. Just as bitcoin is a financial currency, so an educational blockchain could be linked to a currency of intellectual reputation. People can gain credit for carrying out an intellectual task such as reviewing another person's creative work, or can donate small amounts of reputational credit to boost another person's artefact or idea – all recorded and visible on the shared educational blockchain. While blockchain technology opens new possibilities for trading educational reputation as a currency, it also raises significant concerns about treating learning as a commodity to be bought and sold.

Introduction

This is the fifth in a series of annual reports on innovations in teaching, learning and assessment. The Innovating Pedagogy reports are intended for teachers, policy makers, academics and anyone interested in how education may change over the next ten years.

This report is the result of collaboration between researchers at the Institute of Educational Technology in The Open University, UK, and the Learning Sciences Lab at the National Institute of Education, Singapore. We have shared ideas, proposed innovations, read research papers and blogs, and commented on each other's draft contributions. We worked together to compile this report by listing new educational terms, theories, and practices, then reducing these to ones that have the potential to provoke major shifts in educational practice. This 2016 report introduces ten pedagogies that either already influence educational practice or offer opportunities for the future. By 'innovative pedagogies', we mean novel or changing theories and practices of teaching, learning and assessment for the modern, technology-enabled world.

“The method of design-based research has been widely adopted for educational innovation.”

Together, the five reports have described 41 innovative pedagogies. Some of these have already had a major impact on education worldwide. Over 30 million people have engaged with massive open online courses (MOOCs), which we introduced in our 2012 report. MOOCs are now evolving into new types of pedagogy, including massive-scale social learning that applies techniques from social networks (such as Facebook and Twitter) to help people comment on topics, share and 'like' ideas, and review contributions from other learners.

With so many new and emerging pedagogies, the obvious question for teachers and education policy makers is "which ones should we adopt?" Where is the evidence that helps us decide whether to explore adaptive teaching systems (described in our 2015 report), to teach science through threshold concepts (2014), or to embrace dynamic assessment (2014)? Fortunately, alongside these innovative pedagogies has come a new science of learning, where findings from neuroscience, cognitive sciences, educational and social sciences are combined to produce a deep understanding of how we learn. Recent studies have compared different methods of teaching in classrooms and online to reveal which methods increase knowledge, improve exam scores, and keep learners engaged.

There has been a deep, and often justified, resistance from many educational researchers to the 'medical model' of evidence, which treats pedagogies as pills administered to students, tested in the same ways as a new medicine. Learning a topic is not the same as swallowing a pill – it involves a series of mental processes and often-complex social interactions with a teacher and other students. There is no educational equivalent of a 'placebo' (a similar-looking pill with no medical effect). It may take many months or years for the effects of good teaching to become apparent, as skills learned at school or in college are applied in the workplace.

Rather than relying solely on controlled experiments to evaluate new pedagogies, research is now piecing together evidence from multiple sources, rather like pieces of a jigsaw puzzle, to build up a picture of effective methods of teaching, learning and assessment. The method of design-based research has been widely adopted for educational innovation. Researchers using this approach carry out a series of trials of a new method of teaching, with each trial (or 'design experiment') leading to improvements in the method and insights into learning theory and practice.

Cooperative learning

The most obvious success has been in cooperative learning. Until the 1970s, most research in educational innovation was directed towards individualised instruction – how to match teaching content to the needs and activities of individual students. Then, findings from social psychology began to show the value of working together. When students cooperate in small groups of between four and eight people, this can result in greater creativity and better outcomes than working alone. Over the past 40 years, hundreds of studies in labs, classrooms and online, have uncovered conditions for successful cooperative learning. For groups to work well, they need to have shared goals, each person should know how and when to contribute, and everyone should make an appropriate contribution. They should share rewards such as group marks in a fair way, and members of a group should all have opportunities to reflect on progress and to discuss contributions. For many students, learning in groups is not a natural process, and they need to learn how to cooperate by arguing constructively and resolving conflicts. The key phrase is 'positive interdependence' – everyone sees the benefits of learning together and works to achieve the group's goals. All over the world, schools and colleges now make time for group learning activities, founded on these principles of positive interdependence.

Collaborative and social learning online

More recently, learning through positive interdependence has been extended to collaborative and social learning online. Here, the groups may be looser and less coherent, without shared goals. For example, the learners may be people from around the world who have signed up to study a six-week MOOC. The learning benefits come from sharing ideas and perspectives through discussions and constructive argument.

The effects of such online computer-supported collaboration are much harder to measure than for group work in a classroom. A recent study has made an ingenious comparison of the learning benefits of 157 distance learning courses offered by The Open University. Each course had been carefully designed according to a set of pedagogic principles, with differing mixtures of individual and collaborative learning. The university collects the exam scores for all students taking the courses, as well as results from surveys of student satisfaction with the teaching, and data on how many students drop out from each course. From these data the researchers calculated which types of course produced the most successful outcomes.

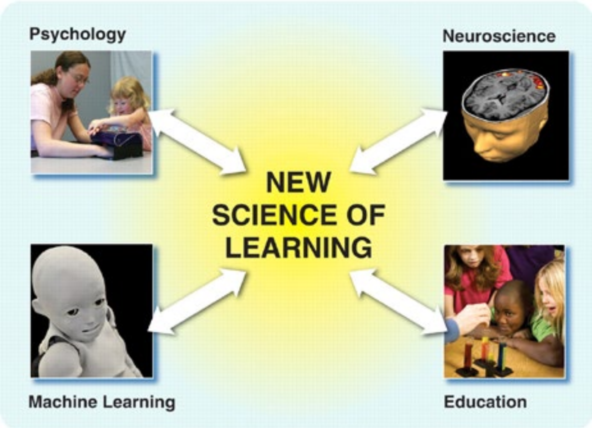
The researchers found that the design of the course had a significant effect on student satisfaction and performance. Students were more satisfied with courses that had a large element of individual reading and watching of instructional videos, but students were more likely to complete courses that had more collaborative learning. Furthermore, exam scores were lower on average for the courses that were based more on individual learning by reading and watching. These findings match other studies showing that although students may be reluctant to take part in group activities, they can benefit from the experience of pooling knowledge and sharing diverse views.

Feedback for learning

Another robust finding from studies of human psychology applied to education is the value of feedback to learning. Feedback can come from a teacher, another more knowledgeable person, another learner, or a computer. It is most successful when the feedback helps a learner to improve, by finding out how to correct a misunderstanding, or to build new knowledge in reaching a goal. I learn something and think

I understand it, I am tested on that learning and find some missing or faulty knowledge, then I am helped to correct it.

It is easier to study the effects of feedback than many other educational methods, so many experiments have been run on whether feedback should be immediate or delayed, positive or negative, and combined with praise or punishment. In brief, giving immediate feedback works best for easy learning tasks and when the student is building knowledge.



Elements of a new science of learning

Both positive and negative feedback can help learning. Negative feedback points out shortcomings and how to correct them; positive feedback can encourage students to continue. There is good evidence that praise alone does not produce learning. Feedback must be relevant to the task and lead to specific action.

Active and constructive learning

Active and constructive learning involves students carrying out an activity that can support learning – such as commenting, critiquing, constructing – while thinking about the purpose and aim of the activity. This contrasts with instructivist learning that mainly involves listening and watching, a lecture for example. A series of studies have compared the sequencing of constructivist and instructivist approaches. They found that students who actively explored a topic (for example, by trying out a science simulation) and then received instruction performed better on tests of knowledge than students who listened to the lecture before active exploration. The method is described later in this report, in the section on Productive Failure. The results are clear, but the explanations of why this happens are still speculative. A plausible explanation is that students who are instructed first and then explore become fixed on the specific items delivered by the lecture, whereas those who explore first gain a broader understanding of the possibilities and dimensions of the topic, which provide a framework for understanding the lecture.

Human memory and learning

The success of active, constructive and collaborative learning raises a question as to how young children learn. Around the age of 8, a typical child is learning to speak about five to eight new words a day, without the mental effort of exploring, discussing, and critiquing. How do they do it, and could that same accelerated learning be adopted or re-discovered in adulthood?

Making associations, such as "hello – bonjour", is the basic process of learning. Studies of associative learning began over 100 years ago. They show that trying to cram lots of facts and associations into memory does not work. Instead, we need to space the practice over time, so that the learning is repeated just as the association is fading from memory, for example at 5 seconds, 25 seconds, 2 minutes, 10 minutes, 1 hour, 1 day, 5 days, 25 days, 4 months and 2 years. Rather than just viewing the association at these intervals, it is better to try to recall it. For example, learners might be asked, "What is the French for 'hello'?" while using 'flash cards' with the English word or phrase on one side and the French on the other. Many language-teaching methods are based on this method of spaced repetition. It is at the core of successful learning platforms such as Memrise and Duolingo.

Spaced repetition on flash cards is successful for making memory associations, such as learning vocabulary or multiplication tables. A similar method has been shown to work for more complex topics. A method called 'spaced learning' builds on findings from neuroscience that explain how humans form long-term memories. Things we remember in short-term memory fade rapidly, but if they are transferred to long-term memory they can last a lifetime. The neuroscience studies show that permanent neural connections are more likely to be made when a brain cell is stimulated at intervals than when it is constantly stimulated. This is good evidence for learning by spaced repetition and it is already being applied to the teaching of curriculum subjects.

In a spaced learning session, students are given intensive teaching by lecture for 20 minutes or less. They then take a short break from mental effort by doing a sports activity or physical exercise. After this, the same or similar content is repeated for 20 minutes, followed by more physical activity, with a final teaching session to focus on applying the knowledge or skills the students have just acquired. A controlled study that compared one hour of spaced learning for school biology with a four-month course of classroom teaching found similar learning benefits. This is the nearest that education gets to a 'learning pill', so it has attracted media attention. It is still research in progress, though it is based on a century of research into human memory and learning. The studies are being repeated, with some variations, in 15 schools over an academic year.

A new science of learning

The cognitive and social processes involved in learning fundamentals of Biology may be very different to those required for discussion on MOOCs. Research is combining observations of learning in classrooms and online, controlled psychology experiments, investigations of human brain functioning, and computational models of machine learning. Together, this work is establishing a new science of learning. Researchers piece together the evidence to form a composite picture of how people learn, individually and together, with and without the support of a teacher, at different ages and in differing cultures. This new science of learning can already help in predicting which innovative pedagogies might work in which contexts.

New pedagogies based on principles of cooperative learning are likely to be successful when the students have shared goals, similar motivations to learn, and time and ability to reflect. These conditions may apply, for example, to professional development in the workplace. Findings about collaborative and social learning can inform the design of pedagogies for learning at massive scale, where the diversity of views create a 'social network effect' of vibrant discussion but with a need to manage and contain the discussions.

Research into feedback for learning is already leading to new forms of assessment (see Dynamic Assessment in the *Innovating Pedagogy 2014* report) and to computer-based systems for adaptive teaching (described in *Innovating Pedagogy 2015*). The value of active and constructive learning underpins many recent innovations described in our previous reports, such as Citizen Inquiry (2013), Flipped Classroom (2014), and Computational Thinking (2015). The neuroscience of human memory may provide a basis for new pedagogies of accelerated and optimized learning.

Amongst all this innovation in teaching, learning and assessment, some principles endure. The teacher still performs a central function, but that is changing from delivery of educational content to facilitating discussion and reflection. Structure is still important, perhaps even more than it was before, as we discover effective ways to initiate, embed and extend learning. Learners still need appropriate goals and support. Most important, learning is a collegiate process. It works best when people want to learn, enjoy the process and support each other. The next decade of innovating pedagogy may focus less on the individual elements of instruction and more on how to merge the new pedagogies into an effective process of lifelong learning.

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Learning through social media

Using social media to offer long-term learning opportunities

Potential impact: Medium
Timescale: Ongoing

Millions of people access sites such as Facebook and Twitter to keep in touch with their friends and exchange information. In China, over a billion people use the single WeChat site to send text messages, share photos, hold videoconferences, read news, write blogs, find friends, order taxis, transfer money and buy goods.

Most of these activities could only be described as 'learning' in the loosest sense of the word. However, social media can bring learning to life by summoning up different times, spaces, characters and possibilities. They can support creativity, collaboration, communication and sharing of resources. These media support exploration of the past and outer space in real time, engaging learners in new ways. They can be used to develop extended projects for learning on a grand scale.

Where the pedagogy is successful, social media can give learners reliable and interesting content, as well as opportunities to access expert advice, to encounter challenges, to defend their views and to amend their ideas in the face of criticism. Where the pedagogy is unsuccessful, sites may present learners with inaccurate information, biased comments and hostile responses. Educators on social media sites designed to offer learning opportunities therefore have multiple roles that differ from a teacher in more formal settings. A facilitator is needed to initiate the project and to take on the tasks of filtering resources and engaging people. Unless the projects have experts to inspire and engage people, the project falls flat, because no one is required to participate. Anyone can engage at any time, anyone can leave at any time, but skilled facilitators can keep people engaged and actively contributing for many years.

Real–time World War II

One example of learning and teaching through social media is @RealTimeWWII, a Twitter account with over 350,000 followers. The goals of the project are to educate followers about the sequence of events in World War Two and to give a sense of what the war felt like to ordinary people.

The author bases his tweets on eyewitness accounts, photographs and videos, giving the impression that his tweets are coming straight from the time. He includes views from around the world, some commenting on well-known events, some giving the view of a private individual. The war is presented and experienced through the words of people who were involved.

The account includes events that were not widely known at the time, but that we now know were significant. For example, tweets in August 2016 outlined treatment of Roma people at Auschwitz, the thousands of deaths from disease and starvation, the many murders and the experiments on children

People around the world engage with this project, re-tweeting resources or providing links to their own selection of tweets. Some Twitter accounts translate the thousands of tweets into languages including Chinese, Italian, Turkish, Latin and Finnish. Others contribute to the conversation with reflective posts that link the tweets with current events.

“social media can bring learning to life by summoning up different times, spaces, characters and possibilities”

World War II propaganda poster from @RealTimeWWII. This resource was shared 375 times by readers.

Pepys' diary

Another project that encourages reader participation is PepysDiary.com. This uses historical material from a single writer, Samuel Pepys, who lived in London during the 17th century. For nearly ten years he kept a private diary.

Pepys' journal provides a first-hand account of national events, as well as detailed descriptions of day-to-day life and his sexual adventures. It is a key primary source for English history of that period. It is also long and sometimes difficult to understand. Usually only highlights are shared, particularly Pepys' accounts of the Great Fire of London.

PepysDiary.com restores the diary to an account of daily life by publishing its full text, day by day. The shared timescale provides a sense that Pepys and the reader are moving through time at the same pace.

@Samuelpepys also tweets several times a day, and has more than 52,000 followers. Although it is clear that Pepys has been dead for 300 years, his tweets provoke a social response. Sometimes these are brief, throwaway comments; others suggest a continued engagement with the character.

The site encourages readers to engage by sharing ideas and collaborating on the project. By the time the entire diary had been posted online, the site had been annotated almost 60,000 times. Now that the diary is being posted for the second time, readers are adding new ideas as well as continuing discussions that began in the comments section ten years ago.

Chaucer and medieval literature

Pepys Diary and *@RealTimeWWII* both use direct quotes from historical sources to bring the past to life. *Chaucer Doth Tweet* takes another approach, constructing a character in order to engage people with medieval literature.

Chaucer was a medieval poet who wrote in Middle English. His spelling, references and vocabulary are often difficult for modern readers to understand. Nevertheless, the quality and impact of his writing mean that it is still well known. His poem *The Canterbury Tales* has often been reworked as drama and film.

A version of Chaucer has now been active on social media for more than ten years. 'Geoffrey Chaucer' began his blog with a post in Middle English on Internet abbreviations. Once his blog was well established, he started to tweet as *@LeVostreGC*. The author behind this character is a lecturer who is fascinated by the possibilities that Chaucer's work opens up for interpretation and for play.

The blog and Twitter stream are not intended as first-hand accounts of medieval life. Instead, they create a world in which the 21st century and the 14th century collide in unexpected ways. Mismatches and anachronisms are skillfully woven together in Middle English.

Chaucer Doth Tweet

Spydere man spydere man
Doth al things a spydere kan
Sondry webbes he kan weaven
Thieves lyke flyes he kan cacchen
Lo anon comth spydere man

The learning possibilities come from the author's ability to bring a language to life. In these tweets and posts, Middle English is presented as an inventive and amusing medium to be read for pleasure. Comments and responses allow people to try the style for themselves.

@LeVostreGC prompts readers to explore other works from the period and to consider the different characters and styles of their writers. He answers questions, offers links to more academic sources, and provides accessible and helpful information. He is also responsible for an annual celebration of dead languages, 'Whan That Aprille Day'. This prompts readers to bake cakes, produce videos, sing songs and generally engage with activity in languages from the past.

NASA

Social media support learning about distant times. They can also help us to learn about different spaces. In the USA, the National Aeronautics and Space Administration (NASA) uses a range of social media to share its work. Each NASA spacecraft has its own Twitter account and personality.

Engaging with these spacecraft produces a variety of learning opportunities. A well-known example is NASA's Mars Phoenix lander, which attracted 300,000 followers on Twitter. All of them were able to receive regular updates on the lander's activity. These updates included the first announcement that water had been found on Mars.

NASA also engages learners in exploration and discovery through *NASA Social*. This includes in-person events and provides opportunities for its social media followers to learn and share information about NASA missions, people and programmes.

For those who want to learn more, *NASA Solve* enables people to engage in the USA's aerospace programme. The site invites members of the public to contribute their time and expertise in order to advance research and solve problems. Projects include crowd-sourced challenges, citizen science projects and competitions for students.

Conclusions

Social media make it possible to involve and draw on the experience of people around the world. The projects described here have all developed over time. Each one allows learners to engage by establishing and maintaining links to events that are remote in time or space.

Running projects like these requires commitment over time as well as expertise, enthusiasm and the ability to coordinate and facilitate. The coordinator must be able to inspire and engage people, because anyone can join at any time and anyone can leave at any time. A skilled facilitator can keep people engaged and actively contributing for many years.

Although these social media projects bring large numbers of learners together internationally, each one has an individual at its heart. These individuals have no set programme of study for others to follow. They have an area of expertise and they use this expertise to filter ideas and resources, to facilitate engagement and interaction. They may also act as co-learners, open to new ideas, and willing to engage with developments suggested by other participants.

In this role, they manage a learning space that has multiple entrance and exit points. In a space that an individual may find accidentally and with no intention of staying for long, they offer ways of engaging at different levels – attracting people to stay and learn when there is no compulsion to do so. On these sites engagement is under learners' control. They can engage very briefly, they can learn by watching others, or they can engage extensively over a long period of time.

Resources

‘The Tweets of War, What’s Past is Postable’ in *The New York Times*:
www.nytimes.com/2011/11/28/arts/re-enacting-historical-events-on-twitter-with-realtimewwii.html

Tweets in real time from the Second World War:
twitter.com/RealTimeWWII

Pepys’ diary in blog form:
www.pepysdiary.com

Associated Twitter account:
twitter.com/samuelpepys

‘Geoffrey Chaucer’ blog:
houseoffame.blogspot.co.uk

Collected posts from the Chaucer blog, along with essays about the blog and medieval scholarship:
Bryant, B.L. (2010). *Geoffrey Chaucer Hath a Blog: Medieval Studies and New Media*. New York: Palgrave Macmillan.

Whan That Aprille Day, 2016:
twitter.com/hashtag/whanthataprilleday16

NASA social media:
www.nasa.gov/socialmedia

Case studies of using virtual media to enhance learning about the real world:
Sheehy, K., Ferguson, R. & Clough, G. (2014). *Augmented Education: Bringing Real and Virtual Learning Together*. New York: Palgrave Macmillan.

Productive failure

Drawing on experience to gain deeper understanding

Potential impact: High
Timescale: Medium (2-5 years)

In productive failure students try to solve complex problems before being taught the relevant principles and correct methods. Their initial efforts at problem solving may cause them to fail or find a poor solution, but the process of exploring different paths can lead to deeper understanding. The teacher then explains the correct solution and its underlying principles.

Impasse-driven learning

The theory of learning through productive failure has its roots in work by Kurt VanLehn and colleagues on impasse-driven learning. They found that learners sometimes reach a block (or impasse) when trying to solve a problem. If they are working alone, they try to find a way round the impasse by identifying a solution, which may or may not be correct. Consider a child who is faced with the subtraction sum:

$$\begin{array}{r} 35 \\ -\ 17 \\ \hline \end{array}$$

but has not learned how to subtract a larger number in a column from a smaller one. The child might try to get round the impasse ('I don't know how to take 7 away from 5') by taking the smaller number from the larger one, with the wrong result:

$$\begin{array}{r} 35 \\ -\ 17 \\ \hline 22 \end{array}$$

A teacher who understands that the child is being entirely rational in trying to solve the problem, but just has some missing knowledge, can then help by supplying the correct knowledge.

Mechanisms of productive failure

Manu Kapur suggests that this process of failure and repair can be an effective form of learning. He proposes that students should work in groups to solve difficult problems. Often they will fail, but that failure may cause them to explore the problem in more depth. They may go back to basic principles, or they may be creative and look for alternative routes to the solution.

There are four key learning mechanisms behind productive failure. Learners

1. access and explore their prior knowledge in relation to the problem or concept,
2. attend to important parts of the problem,
3. discuss and explain these critical features,
4. organise these important conceptual features and include some of them in a solution.

These can be planned into problem-solving lessons in two phases. The first phase encourages students to explore a problem and generate possible solutions (mechanism 1). The second phase teaches the important concepts and helps students to build these into a correct solution (mechanisms 2 to 4).

> “students try to solve ill-structured problems first, and then receive direct instruction”

For example, when teaching the statistical measure of standard deviation, students might be presented with a complex data analysis problem: calculate the most consistent tennis player in an annual tennis tournament over a three-year period. During the first phase, the students work in small groups to produce answers. In the next phase, the teacher gathers, compares and contrasts the student-generated solutions. The teacher then explains how to find the answer, using the student solutions as examples. Finally, the students are asked to solve a similar problem using their new knowledge.

Productive failure compared to traditional teaching

In typical direct instruction, teachers give students content and concepts, then the students practise using a variety of exercises. For productive failure, the order is reversed, so students try to solve ill-structured problems first, and then receive direct instruction.

Since 2008, controlled studies with high school and junior college students in Singapore and India have shown the effectiveness of productive failure, as compared to traditional teaching, for understanding mathematical concepts as well as transferring that knowledge to related problems. Similar findings have also been found in independent replication studies in the USA, Canada, Germany, and Australia. These studies have shown that this technique can effectively be used with learners of various abilities and with different levels of prior knowledge.

Combinatorix interactive tabletop system to explore the mathematics of combinations

A recent study compared two methods of teaching the topic of combinatorics, the mathematics of combinations and permutations. One group of college students watched a video of a university professor giving a lecture on permutations. Then, in groups, they explored the topic with the aid of an interactive table-top display. Another group of students explored the topic first and then watched the lecture. Students who explored first showed significantly greater learning gains. The authors suggest that these students had been primed to understand the lecture, whereas the ones who began by watching the video focused on memorising, recalling and applying the formulas they had been shown.

Conclusions

This pedagogy requires students to manage an open-ended process of challenge and exploration, so they may feel less confident in the short term. The approach helps them to become more creative and resilient over time.

The teacher has a strong presence in learning through productive failure, first setting the problem, then correcting and building on the students' answers. This is a demanding process. It requires the teacher to understand the problem in depth, to be able to discuss and correct the students' faulty knowledge. In order to implement productive failure, school structures and classrooms may have to be revised to give students more time and space for group activities.

Despite being a relatively new pedagogy, productive failure is gaining traction. It has been implemented in over 26 Singapore schools. The Ministry of Education in Singapore has incorporated this approach into the Mathematics A-levels curriculum for junior college students. As an innovative pedagogy, productive failure flips the traditional notion of direct instruction followed by problem-solving and is backed by rigorous empirical testing of its effectiveness.

Resources

Paper on impasse-driven learning and repair theory:
VanLehn, K. (1987). Towards a theory of impasse-driven learning. *Technical Report PCG-1*. Departments of Psychology and Computer Science, Carnegie-Mellon University.
bit.ly/2dIGUCZ

Original paper on productive failure:
Kapur, M. (2008). Productive failure. *Cognition and Instruction,* 26(3), 379-424.
www.manukapur.com/pf/wp-content/uploads/2012/06/ICLS2006-ProductiveFailure-Final.pdf

Study comparing 'exploration first' with 'instruction first':
Schneider, B. & Blikstein, P. (2016). Flipping the flipped classroom: a study of the effectiveness of video lectures versus constructivist exploration using tangible user interfaces. *IEEE Transactions on Learning Technologies*, 9(1), 5-17.

Website describing the pedagogy of productive failure:
www.manukapur.com/research/productive-failure/

Teachback

Learning by explaining what we have been taught

Potential impact: High
Timescale: Medium (2-5 years)

Teachback is a way to understand a topic, and to show that you have understood it, by means of a structured conversation. One person (usually an expert or teacher) explains something they know about a topic to another person (usually someone new to the topic). Then the novice tries to teach their new understanding back to the expert. If the novice gives a good response, the expert goes on to explain some more about the topic. If the novice is struggling to teach back, then the expert tries to clarify the explanation and the novice teaches it back until they reach a shared understanding.

Say, for example, an apprentice is trying to understand the basics of how a car engine works. The experienced car mechanic explains the ‘four-stroke’ engine cycle of sucking in air and fuel, compressing it, igniting it, and pushing out the exhaust. Then the apprentice tries to explain the four stages back to the mechanic, step by step, perhaps with diagrams. If the apprentice makes a mistake, then the mechanic explains again and asks the apprentice to teach back, until they both agree on the explanation.

Learning through conversation

The concept of teachback originated in the 1970s with the educational technologist Gordon Pask, as part of his grand theory of ‘learning through conversation’. Pask emphasised that this method need not always involve a trained teacher or expert. It could involve two people with similar knowledge of a topic – each person in turn asking the other to expand on the topic, and then attempting to explain back, until they both gain a better shared understanding.

Three aspects of teachback are particularly important.

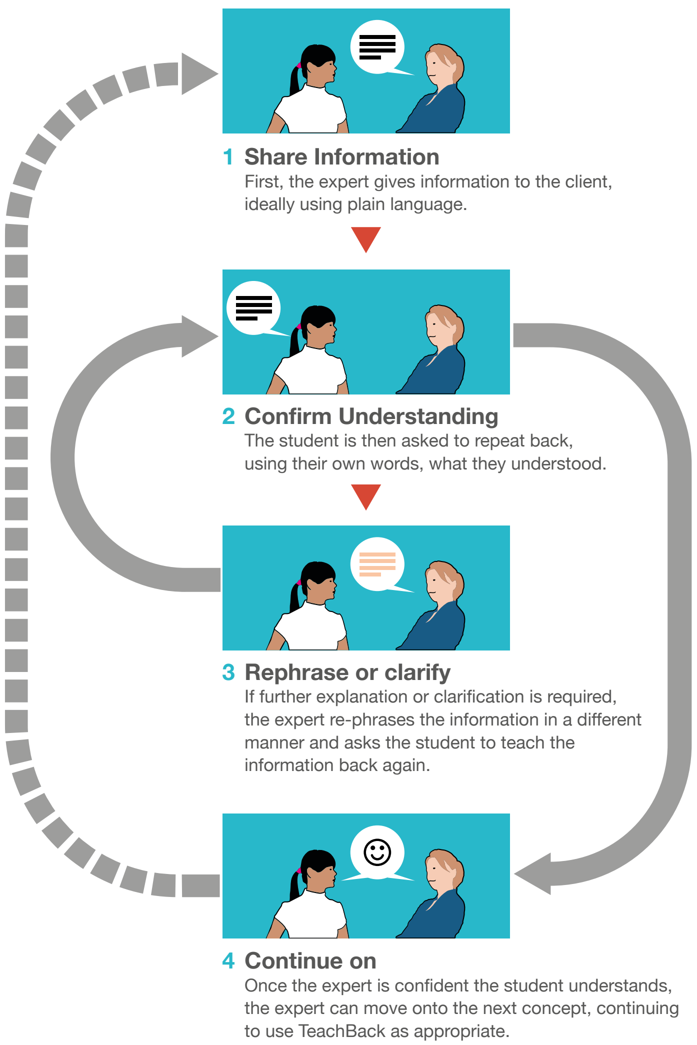
1. The process of learning should be visible and explicit, with the conversations heard by both participants and anyone else who cares to listen.
2. Both partners should gain from the conversation. The one with more expertise has the opportunity to explain that knowledge in a structured way and to find out whether it is being understood. The less-expert person learns by receiving direct instruction and also by going through the process of recalling and teaching back the new knowledge, to find gaps in understanding.
3. There should be some way of verifying the new understanding, for example through a teacher-marked test to apply the knowledge, to ensure that what has been taught is accurate.

Teachback can be used for any type of teaching and learning, including sports coaching, science teaching and language learning. It can also be used for people with similar knowledge to explore a complex topic from multiple perspectives.

Teachback in healthcare

Some medical professionals have adopted a form of teachback to make sure that patients with ailments such as diabetes or heart failure have understood instructions about how to manage their medication. In a study of people with diabetes, 43 patients with low levels of literacy took part in three weekly 20-minute sessions with a nurse. The nurse used teachback methods to confirm their understanding. They asked questions such as, “When you get home, your [husband/wife] will ask you what the nurse said. What will you tell them?” When tested six weeks after the final session, the patients who learned through teachback had significantly better knowledge of diabetes, and of keeping to their diet and medicines, than those in the control group who had spent similar times with the nurse in normal consultations.

Other studies of teachback for patients also found positive results. More research is needed to check whether the results in healthcare are better than other methods such as giving the patient a well-designed leaflet with pictures and talking about it step-by-step.



The teachback process in healthcare

Teachback in the classroom

The teachback method could be used for school and university teaching, but has not yet been widely adopted. A small study of school science students showed that after teaching back their current knowledge (but not receiving any new teaching) the students produced richer diagrams to explain how objects move under gravity than the ones they had drawn before the teachback.

In a school classroom, a teachback session might involve students working in pairs. They start by explaining to each other what they know about a topic. Next, they receive instruction from a teacher or a video presentation. One student in each pair teaches back to the other what they have learned. The other student questions the explanation, using queries such as, "What do you mean by that?" If either is not sure, or they disagree, then they ask the teacher. They may also write a brief explanation, or draw a diagram, to explain their new understanding.

> "we can learn by explaining what we know to another person, who then explains what they know"

Reciprocal Teaching is a similar method to teachback. Students work in groups to read a text, then take it in turns to act as teacher. First, they combine their knowledge to understand what the author means, or to *predict* what will come next in the text. Then, they *question* their knowledge by asking about puzzling information or unclear sections of the text. Next, one of them is chosen to *clarify* the text and attempt to answer the questions. Finally, another student will *summarise* the text by pointing out its most important parts. This is a more complex procedure than teachback and requires a teacher to understand the purpose of each activity and how to assign students to the different roles.

Teachback online

Teachable agents are computer characters that students attempt to teach. In one example, a student starts by creating a picture of the agent on the screen. Then the student goes into the agent's 'brain', shown on the screen as a set of cards representing key concepts of the topic. The student connects these items with arrows to form a concept map. Artificial intelligence software creates a representation of the agent's knowledge, based on what the student has taught it. The agent can answer questions asked by the student, with the concepts lighting up when they are activated. Students then enter their agents in an online competition to discover which one gives the most accurate answers to questions about the topic.

Another variation on teachback comes from Rudman's work on computer-assisted teachback by phone. In this study, one person learns a new topic (herbal remedies) from a book and becomes the teacher. Another person tries to learn about the same topic through a phone conversation with the teacher. The novel part is that the phone conversation is continually monitored by software that recognises keywords in the spoken conversation. As soon as the software recognises a word related to herbal remedies (such as the name of a herb, or its medicinal properties), it displays helpful information on the learner's screen but not on the teacher's screen. In this way, the conversation becomes more balanced. The teacher has some basic book knowledge of herbal remedies, and the learner is provided with instant information to help with asking relevant questions or clarifying the teacher's information.Teachback is a simple but powerful idea, that we can learn by explaining what we know to another person, who then explains what they know. The conversation continues until both reach new understanding. It is used routinely in healthcare to make sure patients understand how to manage their medicines, but has not yet been widely taken up in classrooms.

Resources

An introduction to teachback in healthcare from the Scottish Health Council, with a video of the technique being used for a patient interview:
bit.ly/2aY7bFu

Toolkit to help health professionals learn to use teachback:
www.teachbacktraining.org

The original formulation of teachback from Gordon Pask. The book is a fascinating exploration of how to formalise the learning process, but is a challenging read.
Pask, G. (1976). *Conversation Theory, Applications in Education and Epistemology*. Amsterdam, The Netherlands: Elsevier. A photocopy of the book is available online at:
bit.ly/2aY5Y1c

Review of 12 published articles on teachback for patients. The methods showed positive effects on a variety of outcome measures, though not always statistically significant:
Dinh, T.T.H., Bonner, A., Clark, R. Ramsbotham, J. & Hines, S. (2016). The effectiveness of the teach-back method on adherence and self-management in health education for people with chronic disease: a systematic review. *JBI Database of Systematic Reviews and Implementation Reports*, 14(1), 210-247.

The use of teachback for science learning:
Gutierrez, R. (2003). Conversation theory and self-learning. In D. Psillos, P. Kariotoglou, V. Tselfes, E. Hatzikraniotis, G. Fassoulopoulos & M. Kallery (Eds.), *Science Education Research in the Knowledge-Based Society* (pp. 43-49). Springer Netherlands. An extract with the section on teachback is available at:
bit.ly/2bjO6QA

Study of the use of teachback with diabetes patients:
Negarandeh, R., Mahmoodi, H., Noktehdan, H., Heshmat, R. & Shakibazadeh, E. (2013). Teach back and pictorial image educational strategies on knowledge about diabetes and medication/dietary adherence among low health literate patients with type 2 diabetes, *Primary Care Diabetes*, 7(2), 111-118.
bit.ly/2aWak5y

The method of reciprocal teaching:
Palincsar, A.S. & Brown, A. (1984). Reciprocal teaching of comprehension-fostering and comprehension monitoring activities. *Cognition and Instruction*, 1(2), pp. 117-175.
bit.ly/1mBKkT8

Teachback by phone:
Rudman, P. (2002). *Investigating domain information as dynamic support for the learner during spoken conversations*. Unpublished PhD thesis, University of Birmingham.
bit.ly/2fqslvc

Websites on Teachable Agents, from Stanford University and Vanderbilt University:
aaalab.stanford.edu/research/social-foundations-of-learning/teachable-agents/

www.teachableagents.org/

Design thinking

Applying design methods in order to solve problems

Potential impact: Medium
Timescale: Ongoing

How designers think

The term 'design thinking' was popularised by two books in the 1980s. In *How Designers Think*, the designer and psychologist Bryan Lawson describes design thinking as adventurous generation of ideas combined with focused solving of problems. In *Design Thinking*, Peter Rowe describes processes of design in architecture and urban planning, supported by observations of designers at work.

Rowe describes design thinking as a series of 'skirmishes' or 'engaged episodes' with the problem at hand, exploring the relationships between form, structure, and technical issues. During each skirmish, a typical designer engages in unconstrained speculation, followed by sober reflection to understand the situation. The skirmish takes on a life of its own, with the designer becoming absorbed in its possibilities and constraints. After that, the designer switches to a process of solving problems, working out the issues needed to bring the design into reality.

Thus, design thinking is more than just creativity or 'thinking outside the box'. It involves a series of episodes that combine creativity with critical thinking, followed by analysis and construction. Designers work with the constraints of their materials – concrete and glass for an architect, or colours and computer code for a web designer – employing these constraints as resources to make decisions about what will be elegant and what will work in practice. Designers also backtrack when they reach a mental block, returning to an earlier stage or exploring a different route.

Principles of design thinking

The books by Lawson and Rowe, together with other work, have provided a set of principles for design thinking.

1. Design thinkers embrace diverse perspectives. They explore or develop competing alternatives while making choices. They do not jump to immediate solutions. Having more than one solution or idea allows them to understand the problem and evaluate possibilities.
2. Design thinkers combine interdisciplinary knowledge and skills to generate solutions, which may be based on their practical experience.
3. Design thinkers are focused on products. They understand the properties and constraints of materials, working within these constraints while testing the boundaries.
4. Design thinkers possess strong visual literacy. They sketch and develop their ideas visually. This not only makes the ideas more comprehensible and compelling, but also helps them see pitfalls, misunderstandings and opportunities that verbal discussion may not reveal.
5. Design thinkers do more than resolve technical problems. They explore how their designs will respond to human needs and interests.
6. Design thinkers look beyond the immediate project and its requirements. They understand the process of design and may invent new design tools or improved ways of working for future design effort.
7. Design thinkers are adept team workers who can effectively work in group settings towards a common goal. They develop and apply interpersonal skills to communicate across disciplines and solve problems collaboratively.

8. Design thinkers are oriented to action. They intend to make changes to the world, in small or big ways.

Design thinking in education

As a pedagogy, the essence of design thinking is to put learners into contexts that make them think and work like an expert designer. Design thinking can be applied to any subject area that creates innovative products to address people's needs, including engineering, architecture, medicine, computer programming, website production and creative writing. The principles and practices of design thinking are being adopted for industrial and media design courses in college and vocational education.

> "Design thinkers are oriented to action. They intend to make changes to the world"

A pioneer of design thinking is the Institute of Design at Stanford, also known as the d.school. Its courses and curriculum are based on a process of design thinking, during which students cycle rapidly through a series of processes: observe, brainstorm, synthesise, prototype, and implement. The d.school acts as an innovation hub for Stanford University, taking students from the arts, medicine, education, law and the social sciences for classes and projects. For example, an online crash course in design thinking from d.school provides all the materials needed for a 90-minute exercise in re-designing the experience of gift giving.

In schools and colleges, design thinking activities can be seen as a means to foster innovation, going beyond 21st-century skills of communication, creativity, and digital literacy to embrace civic literacy, empathy, cultural awareness and risk taking. In teacher education, design thinking has been employed to help school teachers with lesson planning.

Typically, students work in pairs or groups on a project of personal meaning or community importance. For example, school students might design a school desk suited to collaborative working, then display their products to other students in an exhibition. One issue in design projects for schools is how to provide the sense of satisfaction produced by a completed design project. Just designing a school desk, but not seeing it built and tested, may leave the impression that design is only a paper exercise. It is better to propose designs that can be constructed and put into use.

Representation of the educational project 'Moscow Through the Engineer's Eyes', an 'Innovations in Education' competition finalist

As with many new pedagogies, a major challenge to the implementation of design thinking is finding ways to align it with the curriculum and exam system. The goal is not for students to master a topic, but to gain enduring competences and dispositions, to think about their everyday world as a set of interlocking designs and its obstacles as design problems. Design work is demanding, intellectually and practically, for students and teachers. Students require modelling and support from teachers. Teachers need repeated practice to become effective facilitators. All must embrace the uncertainties and open-ended nature of design problems, taking a positive attitude to acceptable risk and failure.

Resources

Crash course in design thinking offered by Stanford University Institute of Design:
dschool.stanford.edu/dgift/

How designers address 'wicked problems' that have neither a simple definition nor single solution:
Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues*, 8(2), 5-21.
www.jstor.org/stable/1511637

Detailed study of an interdisciplinary design curriculum in a school, unpacking key characteristics of design thinking:
Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A. & Hornstein, M. (2010). Destination, imagination and the fires within: design thinking in a middle school classroom. *International Journal of Art & Design Education,* 29(1), 37-53.
onlinelibrary.wiley.com/doi/10.1111/j.1476-8070.2010.01632.x/abstract

Three core elements of design thinking explained:
Dorst, K. (2011). The core of 'design thinking' and its application. *Design Studies*, 32(6), 521-532.
www.sciencedirect.com/science/article/pii/S0142694X11000603

Distance learning design students collaborating with vocational learners in a 'makerspace' to take design ideas through to full-scale prototypes:
Gaved, M., Jowers, I., Dallison, D., Elliott-Cirigottis, G., Rochead, A. & Craig, M. (2016). Online distributed prototyping through a university-makerspace collaboration. In: *FabLearn Europe 2016*, 19-20 June 2016, Preston, UK.
oro.open.ac.uk/46704/

Contemporary views on design thinking from the perspective of educational researchers. The book also features illustrative design-thinking activities in education:
Koh, J.H.L., Chai, C.S., Wong, B., & Hong, H.-Y. (2015). *Design Thinking for Education*. Springer Singapore.

Fourth edition of the classic book on design thinking, originally published in 1980:
Lawson, B. (2005). *How Designers Think: The Design Process Demystified* (4th edition). London: The Architectural Press.

Uncovering the thought processes of designers in action:
Rowe, P. (1987*). Design Thinking*. Cambridge, MA: MIT Press.

Design thinking applied to the process of writing:
Sharples, M. (1999) *How We Write: Writing as Creative Design.* London: Routledge.

Learning from the crowd

Using the public as a source of knowledge and opinion

Potential impact: Medium
Timescale: Long (4+ years)

Crowdsourcing involves members of the public giving and receiving information to solve problems, create content, vote for the best solutions, or raise funds. Online crowdsourcing platforms allow amateurs to exchange ideas with experts, combining wisdom of the crowds with expert knowledge and commentary.

Wikipedia is one example of how people work together to produce and negotiate content for the largest encyclopedia in the world. Anyone can add or modify content in Wikipedia. In addition, Wikipedia Administrators act as volunteer stewards, to try to resolve disputes and indicate messy or unfinished articles. Another crowdsourcing website is Kickstarter, which is used to propose projects and raise funds to implement them.

Citizen science

When members of the public participate in scientific or research projects, these crowdsourcing activities are often referred to as citizen science. Science enthusiasts support projects initiated by scientists, by collecting data in their free time. One example is the iSpot platform for the recognition of living things such as birds, plants, and insects. Participants take pictures of species and post them on the site, adding a suggested identification such as “I think this is a Lunar Underwing moth.” Then other, more expert, members of the community help in confirming or correcting the identification.

In event-based citizen science activities, such as the National Geographic bioblitz events, members of the public gather in a park to find and identify all the species in the area. In online citizen science, people carry out investigations or solve science problems. One example is the online game Foldit. People and groups playing Foldit compete to find the three-dimensional structures of protein molecules. In 2011, players deciphered the structure of a virus involved in AIDS, and the results were announced in the scientific journal *Nature Structural & Molecular Biology*.

These citizen science activities give some people opportunities to learn how science projects are run, appreciate nature, and support the work of scientists. Yet the learning is a by-product of the science. New pedagogies of crowdsourcing put the learning first, by engaging citizens to propose projects, recruit participants, collect and verify data, and share and promote findings.

These citizen-led investigations flip the relation with scientists, so that amateurs become active scientists and experts take part as advisors and supporters. The intention is that people will not only learn about scientific topics through running online observations and experiments. They will also come to understand the practices of science and the challenges faced by research scientists, such as asking good questions, recruiting active teams, collecting reliable data, making informed decisions about what to include or reject, and promoting important findings. For example, nQuire-it is an online site that enables anyone to design and run a science investigation. The linked Sense-it app opens the sensors on mobile phones so that participants can use them to collect a wide range of data, such as noise levels, air pressure, or acceleration.

Citizen inquiry on the nQuire-it website

Crowdsourcing in schools

Crowdsourcing can also be connected with school education. The investigation may form part of a worldwide citizen science initiative, such as the EarthEcho World Water Monitoring Day. On March 22nd every year, thousands of schools and individuals test their local water for acidity, oxygen, temperature and cloudiness, sharing results on a world map. Or it could be a local initiative, such as creating a noise map of the surrounding environment.

The teacher will initiate a typical investigation, perhaps using a classroom discussion to develop a guiding question such as, “Are birds affected by noise?” Students discuss ways of answering the question, such as observing whether birds nest near roads, or setting up bird feeders in noisy and quiet areas of the school grounds and checking how much bird seed is eaten. Students are involved not only in collecting data, but also in producing the question and proposing alternative ways to address it. They are also encouraged to recruit friends, family and neighbours as data collectors. The students display and explain their results, pointing out any problems such as unreliable data. They gain the experience of acting as scientists, asking questions that interest them and gaining personal satisfaction from the results.

“ amateurs become active scientists and experts take part as advisors and supporters ”

The teacher has a strong role in such projects, helping to devise a suitable question and method of investigation, and supporting discussion of the findings. Examples of crowdsourced school projects beyond the field of science include interviewing elderly relatives about their memories of childhood, or collecting and mapping photographs of the local area as it was 50 years ago.

Despite the benefits of crowdsourcing to educate the public and put science in the hands of learners, there are challenges to be addressed. An expert may be needed to distinguish a valid investigation from pseudo-science. In school crowdsourcing, the teacher may be faced with the difficult task of collating the data from many students and their friends. It may be difficult to persuade others to join a project. Crowdsourced learning is still at an early stage and more work is needed to develop good ideas and successful online environments.

Resources

EarthEcho World Water Monitoring Challenge:
www.worldwatermonitoringday.org/

Foldit site for challenges to solve protein folding:
fold.it/portal

Foldit players discover the structure of an AIDS virus; with a link to the article published in *Nature Structural & Molecular Biology*:
www.huffingtonpost.com/2011/09/19/aids-protein-decoded-gamers_n_970113.html

iSpot site for sharing and identifying observations of nature:
www.ispotnature.org/

Kickstarter platform to fund creative projects:
www.kickstarter.com

National Geographic bioblitz events to identify species in a specific area:
nationalgeographic.org/projects/bioblitz

nQuire-it citizen inquiry platform and linked Sense-it Android app for collecting data from mobile device sensors:
www.nquire-it.org

https://play.google.com/store/apps/details?id=org.greengin.sciencetoolkit

Wikipedia, crowdsourced online encyclopedia, available in 295 languages:
https://meta.wikimedia.org/wiki/List_of_Wikipedias

Learning through video games

Making learning fun, interactive and stimulating

Potential impact: Medium
Timescale: Medium (2-5 years)

Learning through video games has been around nearly as long as video games themselves. 'Oregon Trail', first developed in 1971, was soon marketed as an educational game that could support study of the history and geography of the United States. The player takes on the role of leader of a train of wagons pioneering a trail to the west coast of the United States in the 1840s. It has sold over 65 million copies and is still the most widely distributed educational computer game.

Many good games are already about learning

One important way to learn through video games is by playing and creating them. Games are now part of the everyday lives of many children – *Minecraft* has over 24 million users worldwide – and many have been adopted in formal education. School classes and online courses teach the principles of video game design and gameplay. Platforms such as *ROBLOX* allow young people to design their own games on phones or computers and publish them for others to play.

James Paul Gee argues that video games have their own pedagogies – they all teach and assess particular skills and dispositions that are relevant within the game. Good games are often long, complex and difficult, but players persist. A successful game is an artful combination of effective game mechanics (how the game unfolds and how players interact with it) and content (the problems players grapple with to advance in the game). These games do not focus on facts and information, but present players with problems that they want to solve, offering both satisfaction and reward when this is done.

The communities that develop around online games have their own distinct pedagogies, sharing shortcuts, tactics and strategy. They provide what Gee calls affinity spaces. In these spaces, learning is proactive but aided; knowledge is distributed and dispersed. There is no age grading, people with different levels of expertise mix together, mentoring others and being mentored in turn. Everyone is always a learner. Learning takes place in such spaces, sometimes involving young people who do not demonstrate high literacy levels in formal education.

By examining how popular games trigger and sustain learning, educators can understand how to apply these to curriculum topics. They include elements such as personally meaningful content, authentic professionalism, embodied learning, productive failure, and learning through play.

In colleges and in secondary schools, such as the Institute of Play's Quest Schools, teachers are teaming up with game designers to address specific learning goals, particularly in areas that students find difficult to understand.

Video game pedagogies

Within video games, players are able to step into unfamiliar roles and contexts, making meaningful and consequential decisions. There is good evidence that video games can improve learning in classrooms. A recent meta-analysis by Douglas Clark and colleagues found that learners made significant gains in both cognitive and intrapersonal learning when they used video games.

Well-designed video games not only help children learn curriculum topics but also improve motivation, intellectual openness, work ethic, conscientiousness, and positive self-evaluation. The gains are equivalent to having a good teacher but not as effective as strong teaching methods such as reciprocal teaching or problem-based learning. Research is continuing to investigate which kinds of


Children designing games in Quest to Learn school

digital games and game-based teaching methods are most effective.

Many effective and popular learning games offer brief and engaging opportunities for learners to engage with distinct content areas and specific skills in a classroom setting that draws on the professionalism of the teacher. Engagement can be extended over time; multiple gaming sessions show significantly better learning outcomes than single play sessions. Games that have ways of tracking achievements and progress, such as points or badges, are more effective than ones that do not.

“ people with different levels of expertise mix together, mentoring others and being mentored in turn. Everyone is always a learner. ”

Games can be used as opportunities for focused practice of specific subject matter. Examples include games that teach fractions as players manipulate geometric shapes to advance through levels, puzzle games exploring states of matter, or a game allowing students to take on the role of a virus to learn about pathogens.

Video games can also be used as units of study embedded within the broader curriculum. The turn-based strategy game ‘Civilization’ has been used to teach world history, demonstrating how material elements influence cultural and economic change. ‘Quest Atlantis’ immerses children aged 9-16 in virtual towns and villages where they are set missions, such as saving a national park from an ecological disaster, that require a combination of social action, environmental citizenship and practical knowledge.

To teachers, these games may not be very different to the project work and roleplay that have been part of history teaching for many years, but video games provide a different way of offering these experiences. Role-playing games do not need to be complex, immersive, or use advanced graphics – realistic graphics seem to have a negative effect on learning.

Games themselves, particularly virtual worlds such as 'Minecraft', can be used as environments for teaching. Simply setting up a virtual classroom misses the point of using games, except when the environment allows for collaboration or feats not otherwise possible. 'Minecraft', for example, can allow students to construct or explore historic sites, re-enact scenes from literature, or experience scientific principles in geology or quantum physics.

Students can also learn by designing video games, and tools for creating such games are increasingly accessible to children. As well as learning design and programming skills, students can work together to create and interact with educational content. For example, children can work in groups to create or extend a virtual environment such as a medieval village or castle, then generate stories by exploring each other's locations and meeting the characters.

Modifying (modding) existing video games offers similar opportunities. Many games, including 'Minecraft' and 'Civilization', allow for the redesign of particular aspects of a game for a given purpose. This allows players to gain further insight by engaging directly with both the mechanics and content of a game.

Drawbacks and future directions

There are clear potential benefits to using video games for learning, with evidence that they can be more successful than traditional classroom teaching. However, they do offer challenges. It is hard to design games that balance learning and fun. Good educational games need to combine appealing content with game mechanics that support learning. Many educational games do not succeed in combining the two. Good games take substantial time, resources, and expertise to develop. One emerging solution is meaningful collaboration between professional game designers, software engineers, and learning experts when designing such games. The games they develop together may include analytics that allow game experiences or classroom curricula to be adapted to gamers' actions and learning trajectories.

Finally, schools may spend badly needed funds on hardware and software in hopes of raising student achievement. However, the technology alone cannot solve this problem. The use of video games for learning requires knowledgeable and supported teachers who can combine them with effective teaching methods. Companies that offer games as a quick fix to teach difficult subjects and improve performance may just be extending inequalities.

Resources

Common Sense Media recommends learning games
www.commonsensemedia.org/best-for-learning-lists

Filament Games sells a range of learning games
www.filamentgames.com/

Institute of Play
http://www.instituteofplay.org/

James Paul Gee blog:
www.jamespaulgee.com/

Gee talking about affinity spaces
https://vimeo.com/10793931

LearningWorksForKids site to find games and apps for children:
learningworksforkids.com/

Minecraft Education Edition:
education.minecraft.net/

'Oregon Trail' is still available for mobile devices:
http://www.hmhco.com/at-home/featured-shops/the-learning-company/oregon-trail

ROBLOX online gaming platform for young people aged 8-18:
www.roblox.com

Systematic review of the effectiveness of video games:
Clark, D.B., Tanner-Smith, E.E. & Killingsworth, S. S. (2016). Digital games, design, and learning: a systematic review and meta-analysis. *Review of Educational Research*, 86(1), 79–122.
www.sri.com/sites/default/files/publications/digital-games-design-and-learning-executive_summary.pdf

Case for educational games and learning through play:
Klopfer, E., Osterweil, S. & Salen, K. (2009). *Moving Learning Games Forward: Obstacles, Opportunities and Openness*. Cambridge, MA: The Education Arcade.
Citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.687.5017&rep=rep1&type=pdf

Edited book with chapters from leaders in the design and study of educational games:
Salen, K. (Ed.) (2008). The Ecology of Games: Connecting Youth, Games, and Learning. Cambridge, MA: The MIT Press.
mitpress.mit.edu/sites/default/files/9780262693646_The_Ecology_of_Games.pdf

Design thinking behind setting up the Quest to Learn school:
Salen, K., Torres, R., Wolozin, L., Rufo-Tepper, R. & Shapiro, A. (2011). *Quest To Learn: Developing the School for Digital Kids*.
mitpress.mit.edu/sites/default/files/titles/free_download/9780262515658_Quest_to_Learn.pdf

Formative analytics

Developing analytics that help learners to reflect and improve

Potential impact: High
Timescale: Medium (2-5 years)

Analytics to support teachers

Learning analytics make use of the data produced during learning and teaching. They help us to understand and improve learning and the environments where it takes place. As institutions and teachers collect more data about profiles and behaviour, they are starting to use learning analytics to predict which students need additional support.

> “analytics *for* learning rather than analytics *of* learning”

Many learning analytics tools in commercial learning management systems such as Blackboard and Desire2Learn, as well as specialised learning analytics tools, collect behavioural data that includes time spent on an online learning unit and performance on an assessment. Using these, they aim to measure and predict the cognitive performance of learners. By identifying who is struggling and at risk of not passing a learning unit, summative learning analytics applications provide teachers with insight into which students may need additional support.

Our previous reports (2012, 2014, 2015) have indicated that learning analytics will become an important innovative pedagogy during 2016-2018. Although some institutions are attempting to optimise learning using insights from analytics, most research and practice currently focusses on *classifying* learning performance of students and showing teachers visualisations of which students are doing well and which might need more support.

Formative analytics for students

While substantial progress has been made in embedding learning analytics in management information systems and teacher dashboards, there is a need to move towards a new approach in learning analytics, which we call ‘formative analytics’. In line with insights from literature on feedback for learning, formative analytics are focussed on supporting the learner to reflect on what has been learned, what can be improved, which goals can be achieved, and how to move forward. By providing analytics *for* learning rather than analytics *of* learning, formative analytics aim to empower each individual learner to reach his or her potential through real-time personalised automated feedback and visualisations of potential learning paths.

Some commercial applications already include forms of personalised automated feedback, giving suggestions about what to study next based on analysis of performance. For example, with the ALEKS tutoring system students are continuously assessed to determine their mastery and understanding of key concepts and their inter-relations. Based upon their learning behaviour, students receive instant formative feedback on what they know and how they can further improve their understanding. They also have the option to choose a new topic that fits with their abilities to learn and their interests.

OU Analyse draws on a range of learning analytics techniques applied to existing distance learning courses to trace what successful students are doing in terms of combinations of learning activities, including contributing to particular discussion forums, watching a key video, or engaging with a specific quiz. The system analyses this information about successful strategies and then provides advice to students who need additional support, or who want to push themselves to achieve excellence.

The illustration shows a dashboard that would provide student Suzie with an indication of how well she is doing relative to her peers who have similar learning paths and personal profiles. Suzie can see whether she is predicted to pass the third assignment in week 12, based on the actions she has taken since the second assignment. Note that Suzie may decide not to participate in the third assignment if she has already accumulated sufficient points, or is not very interested in its topics and judges it not to be important. But if she does want to do well on the assignment, there are specific learning activities that she is recommended, based on data from similar students who have passed this assignment.

There are many ways to track progress and provide feedback to students on whether they are struggling and how to improve. The basic method is to interpret whether activities such as answering a quiz or viewing supplementary material are effective or not, based on the activities of a previous cohort of learners and their exam scores. This approach produces advice such as, "most students who passed this module viewed this document".

Another approach is to compare the behaviour of each learner with the performance of the current set of students, offering advice such as, "Most students have viewed this document" or "The average score for this test is…". More advanced methods of monitoring student behaviour are also possible, such as eye tracking using the camera on a laptop to detect whether a student's attention is wandering. Each of these methods has the potential to provide richer feedback, but could also be seen as intrusive. Alongside ethical concerns about tracking student behaviour are the risks of distracting students from managing their own study by giving them too much guidance. Formative analytics must achieve a delicate balance between support and disruption.

Formative analytics in OU Analyse

Conclusions

As institutions collect more data about learning behaviour, they will be able to show learners how to progress both cognitively and emotionally. Some learners will be discouraged if formative analytics feedback indicates that they are potentially at risk, or they need to complete many more activities in order to pass an assignment. Some may want to see the details of data that determine why certain activities are recommended. Others may just want to know what they should do to achieve a 5% increase in their grade, and how much time this is likely to take. A dialogue is needed between students, teachers, learning designers, and learning analytics experts to decide how formative analytics results and feedback can be most effectively shared with different learners. One obvious approach would be to provide a range of information and automated advice, from simple activity recommenders to more advanced underlying metrics.

Resources

ALEKS system, marketed by McGraw Hill Education, that assesses each student in relation to a topic and gives advice on what to study next:
www.aleks.com

Ferguson, R., Brasher, A., Clow, D., Cooper, A., Hillaire, G., Mittelmeier, J., Rienties, B., Ullmann, T. & Vuorikari, R., *Research Evidence on the Use of Learning Analytics and Their Implications for Education Policy*,(forthcoming), JRC Science for Policy Report, Luxembourg Publication Office of the European Union.

Report on the value of analytics to higher education, including formative analytics:
Higher Education Commission. (2016). From Bricks to Clicks: The Potential of Data and Analytics in Higher Education. London: Higher Education Commission.
www.policyconnect.org.uk/hec/sites/site_hec/files/report/419/fieldreportdownload/frombrickstoclicks-hecreportforweb.pdf

Description of the methods and presentation to the learner of the OU Analyse system:
Kuzilek, J., Hlosta, M., Herrmannova, D. Zdrahal, Z., & Wolff, A. (2015). OU Analyse: analysing at-risk students at The Open University. Learning Analytics Review, 1-16.
oro.open.ac.uk/42529/1/__userdata_documents5_ajj375_Desktop_analysing-at-risk-students-at-open-university.pdf

Tracking eye gaze to understand the relation between students' attention and their performance:
Sharma, K., Jermann, P. & Dillenbourg, P. (2014). How students learn using MOOCs: an eye-tracking Insight. In Proceedings of EMOOCs 2014, European MOOCs Stakeholders Summit, Lausanne, Switzerland (pp. 80-87).
https://infoscience.epfl.ch/record/201916/files/EMOOCS_Sharma-FinalVersion.pdf

Study of the effectiveness of two learning analytics tools (the Concept Trail and Progress Statistics) to give information about students' cognitive activities:
van Leeuwen, A., Janssen, J., Erkens, G. & Brekelmans, M. (2015). Teacher regulation of cognitive activities during student collaboration: effects of learning analytics. *Computers & Education*, 90, 80-94.
www.sciencedirect.com/science/article/pii/S0360131515300439

Learning for the future

Preparing students for work and life in an unpredictable future

Potential impact: High
Timescale: Ongoing

The call to be future-ready is intended to prompt schools and educational systems to prepare their students for success in future learning, work and life. The Skills Strategy produced by the international Organisation for Economic Co-operation and Development (OECD) has shifted the focus away from human capital, measured in years of formal education, towards the skills people acquire, enhance and nurture over their lifetimes. This shift is reflected in educational policy statements and initiatives that aim to equip learners with the skills and dispositions to cope with an uncertain world, a complex life and a changing work environment.

Schools and colleges face continuing challenges when it comes to connecting learning with real-world problems and issues. This results in lack of motivation and learner disengagement. Preparing learners to be ready for higher education, careers and their future life is a universal challenge.

> “learning approaches that teach students to be responsible citizens, contributors and innovators”

One goal is to increase capacity to learn, which presents a new pedagogical challenge in an age of global uncertainty and mobility. How can people shift to understanding learning in terms of human qualities and dispositions, not just the acquisition of knowledge? This shift requires pedagogies that focus on gaining skills to learn and re-learn, including a willingness to change perspective in the light of new information and understanding. It also requires a range of pedagogical approaches that develop resourcefulness in learning, critical thinking skills, and the social skills necessary for learning and working with others.

Preparing learners to be future-ready requires learning approaches that teach students to be responsible citizens, contributors and innovators, equipping them with agency and autonomy in planning what and how to learn, and helping them to develop cultural and interpersonal understanding. Besides developing 21st-century skills such as collaboration, critical thinking, creativity and innovation, they also need to build intrapersonal skills, including persistence and self-regulation. Pedagogies that prepare students to be future-ready support them when learning cognitive skills and knowledge. These pedagogies also help them to develop broader and higher levels of intrapersonal skills and interpersonal skills.

Technology can be used to support the development of these skills, competencies, and dispositions. The US National Education Technology plan for 2016 uses the title ‘Future Ready Learning: Reimagining the Role of Technology in Education’. It advocates giving agency to learners that enables them to make meaningful choices about their learning, and to play a part in their own self-development as their situation changes over time. Giving learners more opportunities to demonstrate agency in learning means providing them with appropriate tools and support, and linking all these with an appropriate pedagogy.

There are many relevant pedagogies, several of which have been discussed in previous Innovating Pedagogy reports. They include:

1. Personalised learning provided with the support of learning analytics.

2. Project-based learning with digital devices to show competency in complex concepts and content, such as carrying out a science project with classmates and publishing the findings online.
3. Moving learning beyond the classroom by, for example, collecting data about wind speed or temperature around a city using the sensors on mobile devices.
4. Pursuing passions and personal interests by posing a question and then using mobile devices to collect and organise evidence outside the classroom in order to answer it.
5. Making transformative learning opportunities available to all learners through online programmes and MOOC courses.

More work is needed to understand how to assess in a formative way the skills and competencies required for future learning. Assessment should provide useful feedback for the learner as well as for the teacher. Teachers lack methods to teach knowledge, skills and dispositions in a coherent ensemble, with guiding materials and assessments. Policy makers need to decide how to make space for these within a crowded school year.

Elements of future-ready learning

The focus in most countries on content and exams means that education systems may need wholesale change to accommodate learning for the future. Finland is often considered to be a model of a successful education system, with learning outcomes near the top of global comparisons for literacy, mathematical literacy and science literacy, and differences between schools that are the smallest in the world. This is achieved with average government investment in school education, small amounts of homework and daily lesson hours, and a school system that is not subject to inspections.

Finland bases its school system on principles of equity, flexibility for lifelong learning, local freedom and responsibility, high quality teacher education, formative evaluation, and support for children with learning difficulties. The country has a core curriculum for basic education, and this is changing to prepare children for the future. The goal is to strengthen each student's image of themself as positive and realistic, discovering the joy of learning, with a strong emphasis on a collaborative school culture and communal methods of studying. The curriculum will make connections between the topics they learn at school and the knowledge they need for their own lives and futures.

As educators, we have much to learn from research findings in the science of learning. We need critical analyses and longitudinal studies of the implementation of future-ready education policy initiatives around the world, to match reality with proposed visions. Educators can contribute to pedagogical, curriculum and assessment frameworks for future-readiness, moving beyond what has already been done for 21st-century skills.

Resources

College and Career Readiness and Success Organizer: overview of elements that affect a student's ability to succeed in college and careers:
www.ccrscenter.org/ccrs-landscape/ccrs-organizer

Niemi, H., Multisilta, J., Lipponen, L. & Vivitsou, M. (eds.) (2014). *Finnish Innovations and Technologies in Schools: A Guide towards New Ecosystems of Learning*. Rotterdam: Sense Publishers.
www.cicero.fi/files/Cicero/site/2121-finnish-innovations-and-technologies-in-schools_ToC.pdf

Office of Educational Technology (2016). *Future Ready Education: Reimagining the Role of Technology in Education* US Department of Education
tech.ed.gov/files/2015/12/NETP16.pdf

P21's Framework for 21st-century Learning:
www.p21.org/our-work/p21-framework

Sheninger, E. (2015). *Leading Future-Ready Schools*. International Center for Leadership in Education, Rexford, USA
www.leadered.com/FutureReadySchools.pdf

Translanguaging

Enriching learning through the use of multiple languages

Potential impact: Medium
Timescale: Medium (2-5 years)

The word 'languaging' describes a dynamic process of using or producing language to make meaning. Languaging refers primarily to verbal communication, but can also include gesturing, body language, drawing, or media production. Moving flexibly and fluidly between familiar languages is known as 'translanguaging'. It can be thought of as the interweaving of multiple linguistic resources, or using more than one language as part of a communicative exchange or self-expression. For example, in a family or among a group of friends, someone may say something in one language while a second person elaborates on it in another; or multiple languages may be employed to find and compare information via web searches on several devices in response to someone's question. These everyday practices already occur in some conversations and exchanges on social media and they facilitate informal learning.

Mobility and language

With the growth of the worldwide web and international travel, an increasing number of learners are studying in a language that is not the one they spoke in early childhood or learned at school or university. A move to a different country for work or education often means that learning will have to be done in another language. Many learners already belong to bilingual or multilingual families, where the languages spoken at home differ from the ones used in school or college. Furthermore, large numbers of learners are joining online courses and MOOCs, or taking part in online discussions on social media, in languages in which they may not be fluent. In many parts of the world, 'standard' English is the language of formal education, although learners come from different language backgrounds. Their other languages may be tolerated in social interactions in the education setting, but sometimes the use of these languages is forbidden. It is still unusual for these other languages to be welcomed into the educational experience and for learners to be able to use them to share their ideas with others or to demonstrate achievement.

This fluid pattern of language education and interaction brings challenges and opportunities. Studying in an unfamiliar language presents learners with challenges they would not face otherwise, which may result in inequality. Learners not only need to understand and respond to educational content, but also join in the social interactions and informal support that come from being able to communicate comfortably in a common language with teachers and fellow students. It may also be more difficult for learners to express their creativity or unique perspective if they are denied the full range of expression that is often taken for granted by those who are proficient in the required language.

> "Translanguaging considers the language practices of bilingual people to be normal rather than strange"

On the positive side, bilingual learners are sometimes able to draw on cognitive resources and skills that are less available to monolingual students. Other learners may benefit from bilingual students' increased awareness of cultural and linguistic differences, if they have opportunities to share that knowledge and experience. This requires a pedagogical approach that acknowledges the value of supporting speakers of other languages to participate fully in the educational experience

Students discuss a topic in pairs using their home language, in TESS-India

and that makes it possible and socially acceptable for them to use other languages in ways that help them and that may also benefit a wider group. Technology can help teachers and learners who want to take that approach.

Translanguaging, pedagogy and technology

Translanguaging strategies for learning usually engage the linguistic repertoires of bilingual students, but they can be extended to bring in language practices of monolingual speakers. Some examples are:

- identify bilingual partners who can help each other;
- design group work with individuals' language backgrounds in mind;
- allow learners to discuss some topics and issues in their preferred language;
- in an online setting, check and negotiate meanings with the support of online resources;
- find multilingual resources and tools and demonstrate to learners their advantages when compared to resources in one language;
- set tasks to search for information in multiple languages or access a wider range of online communities, comments and resources;
- allow learners to use preferred languages when working together to create digital artefacts such as annotated pictures or videos, while ensuring the products are understandable to others;
- co-teach with teachers from a different language background,
- make use of multilingual chatbots or virtual assistants.

For example, a teacher in a rural school in India has many students who are not first-language speakers of Hindi. She started including translanguaging practices in her classes, such as encouraging them to translate Hindi vocabulary into their home language, or reading a page of a Hindi textbook aloud in pairs or groups, then discussing in their home language to understand the meaning of unfamiliar words and make sense of the text. She found a short story that was printed in multiple languages and asked groups of students to read the stories in parallel, then discuss the different versions. The children's confidence in using Hindi has increased, and monolingual Hindi speakers have begun to pick up words and phrases from the other languages.

Tools such as mobile devices, translation software, cross-cultural social networks, virtual assistants, as well as online resources available in other languages, can all contribute to translanguaging among teachers and learners These resources can expand and deepen students' thinking and understanding, enabling them to gain more diverse perspectives from the bilingual learners and other learners. Teachers can also benefit from this experience.

Conclusions

Translanguaging considers the language practices of bilingual people to be normal rather than strange. It extends educational practices that depend on understanding and using standard national languages, to support diversity and encourage integration of mobile and social technologies into everyday communication and learning.

There are risks involved. A pedagogy that is oriented towards supporting bilingual speakers may exclude monolingual learners, or it may take for granted the ability of bilinguals to use their first language effectively for learning. More broadly, supporting translanguaging in education could threaten the survival of 'standard' languages that can facilitate access to education and communication between people from different cultural backgrounds.

If we consider languages to be flexible resources for meaning-making, then traditional boundaries between languages become permeable. Learners and teachers have opportunities to draw on all their linguistic resources instead of being confined to one language. The versatility of mobile and online tools supports this permeability and additional tools to support translanguaging could be developed.

Resources

Example from the teacher in a classroom in India, part of the TESS-India project:
bit.ly/2dYA86g

Educator's viewpoint on translanguaging:
www.literacyworldwide.org/blog/literacy-daily/2015/10/29/translanguaging-to-bridge-the-gap-with-english-learners

Systematic review of research literature on bilingualism:
Adesope, O.O., Lavin, T., Thompson, T. & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research*, 80(2), 207-245.
rer.sagepub.com/content/80/2/207.short

Evidence of intercultural learning in comments on YouTube videos:
Benson, P. (2015). Commenting to learn: evidence of language and intercultural learning in comments on YouTube videos. *Language Learning and Technology*, 19(3), 88-105.
llt.msu.edu/issues/october2015/benson.pdf

Translanguaging as a pedagogy:
Creese, A. & Blackledge, A. (2010). Translanguaging in the bilingual classroom: a pedagogy for learning and teaching? *The Modern Language Journal*, 94(1), 103-115.
www.education.leeds.ac.uk/assets/docs/simpson/creese_blackledge_mlj_paper.pdf

Introduction to a special issue on digital literacies and language learning:
Hafner, C.A., Chik, A. Jones, R.H. (2015). Digital literacies and language learning. *Language Learning and Technology*, 19(3), 1-7.
llt.msu.edu/issues/october2015/commentary.pdf

Analysis of a Serbian student's multilingual practices on Facebook:
Schreiber, B.R. (2015). "I am what I am": multilingual identity and digital translanguaging. *Language Learning and Technology*, 19(3), 69-87.
llt.msu.edu/issues/october2015/schreiber.pdf

Blockchain for learning

Storing, validating and trading educational reputation

Potential impact: High
Timescale: Long (4+ years)

Part of the process of learning is the use of testing, examinations and qualifications to demonstrate that we have learnt something. This requires a secure and efficient way of storing results and tracking back to judgements and approvals. Until now, this has been managed by established organisations that provide formal exams, accreditation and qualifications. The records are stored by the organisation and the student is given a paper certificate.

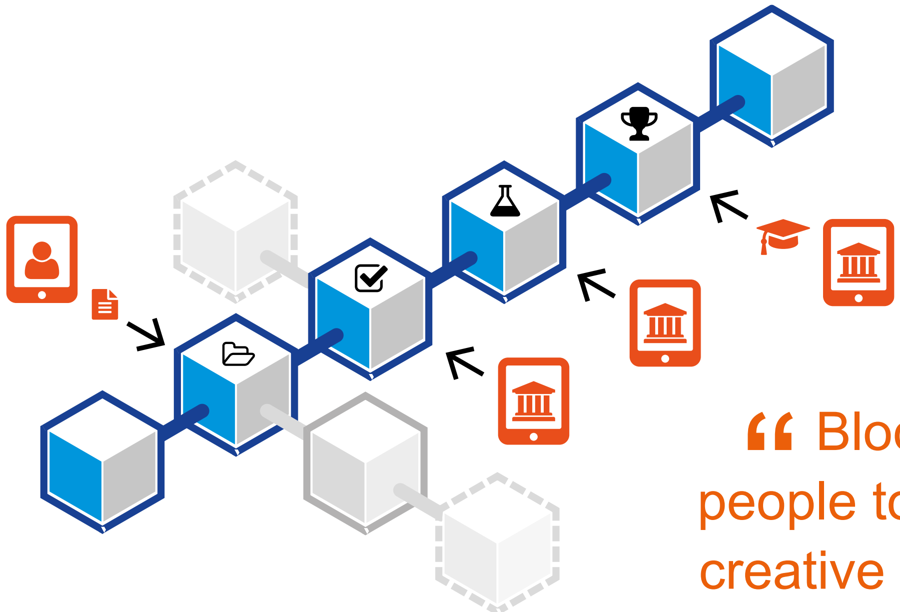
A new technology, the blockchain, offers a digital system that can reliably store many kinds of educational record, from a degree certificate to a student essay or a video of a dance performance, in a universal record that is not held in one institution but is copied across many computers. Blockchain allows people to show their own creative works and ideas to the world, staking a claim for invention and gaining recognition.

Blockchain is the database technology of the Bitcoin currency. It offers a secure, distributed and low cost way to store records and validate any transaction that can be represented digitally. The blockchain is a long chain of data items (which could be text, images, video, software) linked to each other and stored as identical copies on every participating computer. It uses modern data security methods to make sure that items in the chain cannot be altered.

To add a new item to the chain requires evidence that the provider is sincere and trustworthy. Various automated methods can help to provide that evidence. For example, you might have to perform a difficult computing task to add a new item, or be a trusted provider. The blockchain can also hold segments of computer code that manage transactions such as automated invoicing, enabline each transaction to be digitally validated without relying upon a single authority. This has worked so effectively that the Bitcoin currency has grown since its release in 2009 to represent a market of over $10 billion, based on the trust that can be placed in digital proof provided by the Bitcoin blockchain.

A blockchain for education works in the same basic way, storing educational items, such as certificates and creative works, on a public record spread across thousands of computers. In terms of its value for pedagogy, the important aspects are that the blockchain is secure, accessible, distributed, and can hold many types of educational item (or links to those items to save filling up computer memories). One use is to store exam records and degree certificates, along with the date each was registered and the organisations involved. Instead of an employer contacting the university to verify a graduate's qualifications, these can be checked using the company's copy of the blockchain. The University of Nicosia was the first higher education institution to store its exam certificates on the Bitcoin blockchain.

This method can be extended to small chunks of achievement. Learning can be recognised at different levels, from small learning events (such as completing an online course or taking an evening class) up to a university degree that takes many years. Some organisations (covered in *Innovating Pedagogy* 2013) already use digital badges to accredit learning. These badges can now be recorded on a blockchain, strengthening the reliability and global accessibility of the badges. Individuals could add items to the blockchain, such as works of art, literary creations, academic papers, or records of invention, to provide a secure public record of their work and its date.



Representation of blockchain for learning

A further step is to allow transactions, similar to Bitcoin payments, of educational reputation rather than money. One way of doing this would be to assign an initial amount of reputation to institutions and individuals, based on their status. This could be related to their standing in international league tables or to significant achievements, such as earning a Nobel Prize. They can then award small amounts of this reputational currency to students who graduate, or colleagues whose work they value. Organisations and individuals could gain further reputation by providing recognised services to education, such as providing open courses, or funding research. The record is public, so anyone can see how a person gained educational reputation, and the rules for adding new value are agreed by consensus.

The idea of mining and trading reputation may sound bizarre, but similar mechanisms form the basis of successful organisations such as Uber and Airbnb. Technologies are already in place for learning on the move, rating teachers and students, making donations, tracking contributions to knowledge, and awarding small amounts of educational credit. The blockchain makes this process more open and visible.

Sony Global Education is proposing to set up a separate educational blockchain to store records of achievement. Other organisations, such as The Open University, are experimenting with new educational services on existing blockchains. This technology could appeal to existing institutions wanting to move towards digital operation. As with other open online approaches, there is also the potential to disrupt current business. Generating trust digitally means that the evidence can be distributed and there is less need for a single, central established authority. Blockchain technology could become an enabler for many innovative pedagogies discussed in our previous reports, including crowd learning, rhizomatic learning, citizen inquiry, massive open social learning, and maker culture.

> “Blockchain allows people to show their own creative works and ideas to the world, staking a claim for invention and gaining recognition.”

The analogy with Bitcoin is not perfect. Part of the success of Bitcoin as a currency is that the system makes it costly to generate new coinage and the process of mining becomes more difficult over time. The incorporation of cost is useful in commerce and builds in a profit motive for being involved in running the distributed system. A system based on trust and educational reputation would need to be managed in a different way, for example with organisations and individuals gaining a level of recognition before they are able to add items to the blockchain and ‘mine’ new reputation. The challenge is to open up education to anyone with good ideas to share, rather than just reward existing élite institutions and a small community of scholars.

Resources

Comprehensive introduction to the blockchain for education:
hackeducation.com/2016/04/07/blockchain-education-guide

Experimenting with the Ethereum blockchain for portfolios, badges and peer reputation:
blockchain.open.ac.uk/

Fictional, yet plausible, future system powered by blockchain technology:
teachonline.ca/tools-trends/exploring-future-education/uber-u-already-here

How blockchain could disrupt higher education:
campustechnology.com/articles/2016/05/16/how-blockchain-will-disrupt-the-higher-education-transcript.aspx

Short explanation of Bitcoin and blockchains:
http://www.dontwasteyourtime.co.uk/technology/bitcoin-and-blockchains-explained/

Sony Global Education is developing a blockchain to share educational records:
www.sony.net/SonyInfo/News/Press/201602/16-0222E/index.html

University of Nicosia academic certificates on the blockchain:
digitalcurrency.unic.ac.cy/free-introductory-mooc/academic-certificates-on-the-blockchain/

Devine, P.M. (2015). Blockchain learning: can crypto-currency methods be appropriated to enhance online learning? *In Proceedings of ALT Online Winter Conference 2015*, 7-10 December 2015.
oro.open.ac.uk/44966/

Sharples, M. & Domingue, J. (2016). The Blockchain and Kudos: a distributed system for educational record, reputation and reward. In K. Verbert, M. Sharples & T. Klobučar (Eds.) *Adaptive and Adaptable Learning: Proceedings of 11th European Conference on Technology Enhanced Learning (EC-TEL 2015)*, Lyon, France, 13-16 September 2016. Switzerland: Springer International Publishing, 490-496.
oro.open.ac.uk/46663/

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