Innovating Pedagogy 2017

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

Rebecca Ferguson, Sarit Barzilai, Dani Ben-Zvi, Clark A Chinn, Christothea Herodotou, Yotam Hod, Yael Kali, Agnes Kukulska-Hulme, Haggai Kupermintz, Patrick McAndrew, Bart Rienties, Ornit Sagy, Eileen Scanlon, Mike Sharples, Martin Weller, Denise Whitelock

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Institute of Educational Technology, The Open University,
Walton Hall, Milton Keynes, MK7 6AA, United Kingdom

The Learning In a NetworKed Society (LINKS) Israeli Center of Research Excellence (I-CORE), University of Haifa, Abba Khoushy Ave 199, Haifa, 3498838, Israel
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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 sixth 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 In a NetworKed Society (LINKS) Israeli Center of Research Excellence (I-CORE). 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 secondary and tertiary 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 Lastly, we drew on published and unpublished writings to compile the ten sketches of new pedagogies that might transform education.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 **Spaced learning:** It has long been known that we learn facts better in a series of short chunks with gaps between them, rather than in a long teaching session such as a lecture. Recent research in neuroscience has uncovered the detail of how we produce long-term memories. This has led to a teaching method of spaced repetition that occurs in the following order: (1) a teacher gives information for 20 minutes; (2) students take a break of 10 minutes to participate in an unconnected practical activity such as aerobics or modelling; (3) students are asked to recall key information for 20 minutes, followed by a 10-minute break; and (4) students apply their new knowledge for a final 20 minutes. A study of spaced learning shows a significant increase in learning compared to a typical lesson. The method has been tested successfully in schools, but a larger-scale trial is needed to show whether it can be implemented at scale.

2 **Learners making science:** Citizens need the skills and knowledge to solve problems, evaluate evidence, and make sense of complex information from various sources. A strong understanding of Science, Technology, Engineering, and Maths (STEM) topics can develop these skills and address current demands for STEM-skilled employees across job sectors. Both these needs are urgent. Enabling learners to experience how Science is made can enhance their content knowledge. It can also develop scientific skills, contribute to their personal growth, and result in identity change and an increased understanding of what it means to be a scientist. These changes can be achieved through participation and contribution to citizen science activities that are personally relevant, promote engagement with both social and natural sciences and scaffold understanding of the scientific method, critical thinking, and reflection.

3 **Open textbooks:** Open textbooks are freely shareable and editable resources designed to operate in place of a specified textbook. As one approach to open educational resources (OER), they are not locked down by copyright restrictions but have an open licence that enables everyone to reuse, remix, revise, redistribute and retain them. Open textbooks can be used to challenge the relationship between students and knowledge. These books are adaptable – not fixed and static resources but dynamic ones. Students can edit and amend an open textbook as part of their study. This helps them to understand knowledge as an ongoing process in which they play an active role. These textbooks can be seen as part of a broader move towards 'open pedagogy', which emphasises open content and open practices.

4 **Navigating post-truth societies:** *Post-truth* was 2016's Word of the Year, according to Oxford Dictionaries. Fake news and information bubbles are not new but awareness of their impact on public opinion has increased. People need to be able to evaluate and share information responsibly. One response is to integrate these skills within the curriculum. However, this raises questions: How can we know which sources to trust? The ways in which people think about such questions are called 'epistemic cognition'. Researchers have developed ways of promoting learners' epistemic cognition. These include promoting understanding of the nature of knowledge and justification as well as fostering abilities to assess the validity of claims and form sound arguments.

5 **Intergroup empathy:** Online environments, such as social media, form global virtual spaces. In these, people from different backgrounds interact with each other, even if they come from countries or cultures that are engaged in conflict. This means that skills such as communication, teamwork, and empathy are important. When groups are kept apart, they are likely to develop negative stereotypes of each other. These stereotypes are associated with prejudice, hostility, and aggression. Members of groups that do not have opportunities for constructive social contact may think in terms of 'us' versus 'them'. This perspective makes it difficult to empathise – to understand and share the feelings of members of the other group. The effects of intergroup conflicts can spill over into online communities, provoking strong negative emotions and the use of stereotypes. In such cases, activities designed to promote intergroup empathy can provide effective responses and help to reduce tensions.

6 **Immersive learning:** Learning based on experience and exploration can be intensified through immersion. It can enable people to experience a situation as if they were there, deploying their knowledge and resources to solve a problem or practise a skill. The learning comes from integrating vision, sound, movement, spatial awareness, and even touch. Traditionally, immersion requires learners to act out scenarios or take part in investigations, with actors and props to simulate reality. By using technologies such as virtual reality, 3D screens or handheld devices, learners can experience immersive learning in a classroom, at home, or outdoors. This enables them to explore possibilities that would be difficult, dangerous, or impossible in everyday life. Participation in well-designed immersive learning is likely to be stimulating and memorable.

7 **Student-led analytics:** In the last decade, learning analytics have helped institutions, teachers, and policy makers to understand student learning and outcomes. These analytics make use of the data generated during study activity in order to enhance learning and teaching. They often focus on how teachers and institutions can help learners to pass a test, a module, or a degree. Student-led

analytics, on the other hand, not only invite students to reflect on the feedback they receive but also start them on the path of setting their own learning goals. These analytics put learners in the driving seat. Learners can decide which goals and ambitions they want to achieve, and which types and forms of learning analytic they want to use to achieve those targets. The analytics then support learners to reach their goals.

8 **Big-data inquiry: thinking with data:** New forms of data, data visualisation and human interaction with data are changing radically and rapidly. As a result, what it means to be 'data literate' is also changing. In the big data era, people should no longer be passive recipients of data-based reports. They need to become active data explorers who can plan for, acquire, manage, analyse, and infer from data. The goal is to use data to describe the world and answer puzzling questions with the help of data analysis tools and visualisations. Understanding big data and its powers and limitations is important to active citizenship and to the prosperity of democratic societies. Today's students therefore need to learn to work and think with data from an early age, so they are prepared for the data-driven society in which they live.

9 **Learning with internal values:** Throughout life, significant learning is triggered, monitored, and owned by us as individuals. This learning is rooted in our own needs and interests and shaped by our internal values. However, schools that are committed to a national curriculum need to conform to a set of external values. These are unlikely to align exactly with the learning that is based on individual students' internal values. Efforts have been made to design and develop programmes that can meet this challenge. The main approach offers students choice about what and how they learn. At the same time, it equips them with means to develop appropriate knowledge, skills and ways of thinking in order to support their learning. This approach balances the learning based on students' internal values with the learning that is required by the normative values of educational systems.

10 **Humanistic knowledge-building communities:** The goal of humanistic education is to help people become open to experience, highly creative, and self-directed. This is a person-centred approach. Knowledge-building communities aim to advance the collective knowledge of a community. This is an idea-centred approach. When the two approaches are combined, they create a new one: humanistic knowledge-building communities. Research shows that students who participate in HKBCs develop their knowledge and selves in integrated and transformative ways.

Introduction

This is the sixth 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 In a NetworKed Society (LINKS) Israeli Center of Research Excellence (I-CORE). 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 2017 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.

> “This year's innovative pedagogies include some that have an urgency about them. They are addressing problems of today's world”

This year's innovative pedagogies include some that have an urgency about them. They are addressing problems of today's world, where learners are faced with fake news, pseudo-science, 'post truth' and increasing tensions between some communities. They are pedagogies that emphasise the importance and the roles of education in the world today.

What is education for?

Since the time of Socrates, philosophers have questioned the purpose of education. Why is it important? What is it intended to achieve? Broadly speaking, they have proposed four answers. Education is intended to train people for employment, to develop good citizens, to socialise people within a community, and to develop happy, rounded individuals.

Training people for employment, moving them 'from learner to earner', is often viewed as the major drive behind education. Employers and governments complain if students do not emerge from formal education with the skills that are necessary in a contemporary workplace. Students are unhappy if their substantial investment of time, and often of money, does not equip them to find a well-paid and fulfilling job.

Pedagogies that focus on summative assessment – a test of what has been learned – align well with this view of education. *Learning Design* can be used to develop courses that include skills for employability or that align directly with a specific choice of career. *Learning Analytics* help students to progress towards the appropriate learning objectives. *Badges* and other forms of accreditation mean that even informal learning, studied outside the classroom, can be added to a CV or resumé and evidenced. *Massive Open Online Courses* can be used to bolster in-service training and continuing professional development. More broadly, *Problem-based Learning* helps learners to develop the skills that they will need in a work environment, where the challenges are not clearly defined and nobody knows the answers in advance.

Developing citizens implies a broader perspective. It offers a reason for educating those who may never enter the workplace as paid employees – perhaps due to illness, family commitments, or a lack of jobs – but who can contribute to society in many other ways. It aligns with the idea of lifelong learning, supporting the provision of education for those who have retired or are no longer able to work. *Learning for the Future*, covered in last year's report, is associated with pedagogies that teach students to be responsible citizens, contributors and innovators, helping them to develop cultural understanding.

Education that develops citizens is typically controlled by governments. They fund the schools and train the teachers. They decide who can go to school, when they can go to school, where they can go to school, and what they must do when they get there. This means that their focus is usually on formal education – particularly on the period of mandatory or near-mandatory schooling. This is the period when the state has most influence on the curriculum and can stipulate what knowledge, skills and values should be taught. Any pedagogy that can be used in a formal setting can be used as a way of developing citizens. Informal pedagogies can be used as well but, by definition, these are independent of the state system.

Socialising the community covers a range of very different possibilities. Ethnic or religious communities can be global in scope, with long-standing and well-established approaches to community life and education. At the other end of the scale are smaller or less formal learning communities that have greater scope for flexibility in their pedagogy and their activities. In between is the profusion of societies, clubs and interest groups that offer training and support for craft skills, community work and sports. In the case of *Rhizomatic Learning* (see previous *Innovating Pedagogy* reports for fuller explanations of all pedagogies listed in italics), the curriculum and subject knowledge are constructed by community members – 'the community is the curriculum'. Communities may also form around a particular pedagogy. This can happen with *Event-based Learning*, which brings people together for a learning purpose, and with *Maker Culture*, which involves a community of peers who can support each other to build things.

Developing individuals has a long history – although ideal individuals are not always expected to be happy or well rounded. The classical version of this aim was a healthy mind in a healthy body. The process of learning can be seen as a fundamental part of life, shaping our identities and helping us to transform our understanding of ourselves. This means *Learning To Learn* is fundamental to any approach to education that is based on the individual. *Incidental Learning* supports individuals to reflect on the learning that takes place during their lives, helping them to understand isolated fragments of learning as part of more coherent and longer-term learning journeys.

Lifelong, lifewide learning

Whatever the aim of education, it has typically been understood as something that we do when we are young, which prepares us for life. Technology has helped to shift that perspective and to extend educational opportunities. Educational resources are increasingly accessible, not just in schools and libraries but also on our tablets and computers in the form of *E-books* and *Open Textbooks*.

Skilled teachers can help learners to benefit from experiences that take place outside the classroom. One way of doing this is through the *Flipped Classroom*, which blends experiences inside and outside school. *Seamless Learning* provides a different approach, connecting learning experiences across settings, technologies, and activities. More broadly, *Crossover Learning* brings together settings and contexts in a 'learning ecosystem' that makes use of technology to establish and reinforce links between learning that takes place inside and outside the formal education system.

These possibilities extend the reach of education. With adequate resources, education can now continue across the lifespan, preparing people for each new phase of their life and for each new challenge. As well as being lifelong, it can also be lifewide – expanding to take in learning opportunities open to us as workers, citizens, community members and individuals.

New pedagogies make use of technologies to go further, to open up new possibilities. Together, learners can engage in *Crowd Learning*. They can update and revise knowledge, offering a more personal and local perspective than centrally published media. They can engage in *Citizen Inquiry* to explore new areas of knowledge and to investigate together. They can use *Bricolage* to put together the materials and resources at hand to explore and develop new methods of learning and teaching. Together, they can take control of their own learning and their own education.

New educational priorities

Phrased in that way, the future looks bright for learners. But pedagogy is concerned with both teaching and learning. Learners do not stand alone – they are supported by teachers. Learners need help to recognise and escape their own filter bubbles, they need support to understand how to assess the credibility of a source, they need an expert to work with them to develop the skills that they need, and they need a guide who can help them to identify routes forward.

The numerous possibilities that are opening up suggest we need a new aim for education. We need an education that develops us not just as workers, citizens, community members and individuals, but as learners. Lifelong learners. Lifewide learners. Learners who can share their knowledge and search for the meaning. Learners who are aware of the crucial importance of teachers and of experts.

This year's *Innovating Pedagogy* report combines two elements of pedagogy. One of these draws attention to how learners can be empowered. They can, potentially, learn faster than ever using *Spaced Learning*. They can work together as *Learners Making Science*, they can immerse themselves in new experiences, they can think with data as they carry out *Big-data Inquiry,* they can develop their own values and their own objectives. They can even reshape their own *Open Textbooks*. These pedagogies point to the possibilities which are being enabled and expanded by developments in technology.

At the same time, the report draws attention to crucial skills that are required as we **educate people to become proficient learners**. These skills include understanding the nature of knowledge, assessing the validity of claims, and forming sound arguments. They include awareness that knowledge is complex, diverse, and constructed within particular perspectives. They include the development of reliable processes and strategies for making sense of the world – such as the scientific method. They include the ability to empathise with others and to judge the merit of different perspectives and narratives. Most important, they include the desire to seek out experts and skilled others who have the ability to help us to progress as learners.

Resources

For more detailed accounts of the pedagogies mentioned in italics, see the past reports on the Innovating Pedagogy website
http://www.open.ac.uk/blogs/innovating/

Spaced learning

Building long-term memories in minutes

Potential impact: High
Timescale: Ongoing

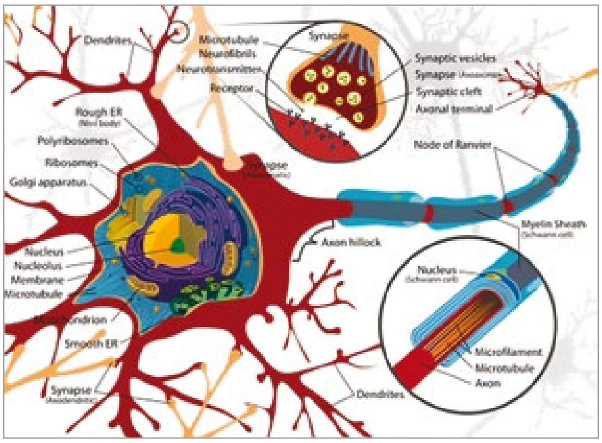
Studies of human memory have shown that we remember more when learning is spaced over time rather than crammed together in a single session. Typically, these studies have focused on learning short items, such as words or phrases in a foreign language, with increasing spaces between attempts to recall the items. For example, a person trying to learn the Spanish for 'What time is it?' (¿Que hora es?) might read the phrase, then try to recall it after five minutes, an hour, a day, three days, and a week. Software such as Anki, Cerego and Memrise uses this method of spaced repetition to teach foreign language vocabulary and other associations, such as the names of national flags and their pictures.

Making memories

The way this is thought to work is that each recall session stimulates the learner's short-term memory for the item and its new association, until these become fixed in long-term memory. The method is generally successful, providing the student is willing to stick with it. However, the learning takes place over days and has been limited to building connections between words, phrases or images.

New research into the neuroscience of learning has now identified how long-term memories can be made in minutes rather than days and for complex topics, not just basic associations. In brief, the human brain contains around 85 billion cells, or neurons. Each can be connected with up to 10,000 other neurons through synapses, tiny gaps that transmit electrical or chemical impulses. As well as being briefly activated by stimuli such as sights and sounds, connections between synapses can be strengthened by persistent chemical changes. These connections are the basis of long-term memories.

Experiments with animal cells have shown that the chemical strengthening between neurons happens while learning and again later, including during sleep. In one study, brain cells removed from a rat hippocampus (the part of the brain used to consolidate short-term to long-term memories) were stimulated with electricity. The researchers found that three bursts of stimulation, with 10-minute spaces between them, produced more active connections between synapses than one long period of stimulation. The spaced bursts also produced a protein in the cells that is observed when long-term memories are being made.



Neuron cell diagram. Neurons are electrically excitable cells in the nervous system that process and transmit information.

A few studies of human brain activity while learning have been carried out. One of these examined magnetic resonance imaging (MRI) brain scans of humans after they had tried to memorise 120 novel pictures of faces. In the 'massed learning' condition each face was presented to adults multiple times, followed by the next face. In the 'spaced learning' condition, the faces were presented in sequence, one after the other. The study showed that spacing out the faces by showing a sequence of different ones produced more activity in the part of the brain linked to face recognition than the massed presentation. There have not yet been any attempts to study effects on the brain of longer spaces (such as ten minutes) between periods of learning.

The evidence, mainly from experiments with animal brain cells, suggests that a period of learning stimulates connections between brain cells. It takes time for the chemical bonds between synapses to strengthen. Trying to learn too much in one session may not give the brain time to embed the knowledge in long-term memory. The animal cell experiments suggest a space of ten minutes between learning episodes.

Spaced teaching of curriculum topics

This is early research and more studies are needed to understand the relations between brain activity and human learning. Based on this work, former head teacher (now researcher) Paul Kelley and brain scientist Terry Whatson have designed a method for spaced teaching of curriculum topics. The teaching consists of three 20-minute sessions, with 10-minute breaks between them.

- **Session 1** (20 minutes) Teacher gives a rapid presentation of a new topic.
- **Break** (10 minutes) Students engage in physical activity, such as juggling or modelling.
- **Session 2** (20 minutes) Students actively recall key concepts from the presentation.
- **Break** (10 minutes) Students engage in physical activity, such as juggling or modelling.
- **Session 3** (20 minutes) Students apply the knowledge through problem exercises.

Kelley and Whatson ran trials of their teaching method with students aged 13–15 who were learning Biology in a UK school. In one trial, students studied an entire first Biology course through spaced learning over a period of 90 minutes. Their exam performance was compared to a control group of students who studied the course in standard lessons over four months. There was no significant difference in exam scores between students who had done spaced learning in a single day and those who studied over four months.

> “ 90 minutes of spaced learning could have the same outcomes as months of study ”

In another trial, students aged 14–15 used spaced learning to revise for a Biology exam. The same students also used traditional intensive revision for a Physics exam. Their exam scores after Biology spaced revision were significantly higher than the national average for similar students. Their exams scores after revising normally for Physics did not differ from the national average.

School trials

These studies, suggesting that 90 minutes of spaced learning could have very similar outcomes to months of study, led to national press coverage. The UK’s Educational Endowment Foundation (EEF) has now carried out a further randomised trial in schools of three different types of spaced learning: 10-minute spaces between teaching sessions, 24-hour spaces, and a combination of 10-minute and 24-hour spaces.

In the combined method, teachers taught Biology, Chemistry and Physics in three 12-minute lessons with 10-minute spaces between each topic. This process was repeated on three consecutive days to give the additional 24-hour spaces. The EEF trial found that this method, combining 10-minute and 24-hour spaces between lessons, brought the best results. Teachers and students appeared to enjoy the programme. This study was only intended to give preliminary evidence and the EEF has recommended a larger trial before drawing firm conclusions about the success of spaced learning.

We still have much to discover about spaced learning. Is it a 'miracle education' method, a slightly more efficient way of revising for exams, or something in between? Is it as successful for learning new material as for consolidating previous knowledge? Most important, does it lead to deep learning, where students retain the new concepts, integrate them with previous knowledge, and gain long-term understanding and skill?

Resources

Report by the Education Endowment foundation on a pilot evaluation in schools of a sequence of lessons based on spaced learning:
https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/spaced-learning/

Review of research literature on spaced repetition:
https://www.gwern.net/Spaced-repetition

Anki spaced repetition flashcard software:
https://apps.ankiweb.net/

Cerego adaptive learning using spaced repetition:
https://www.cerego.com/

Memrise language learning using spaced repetition:
https://www.memrise.com/

Report of study to stimulate rat brain cells:
Fields, R. D. (2005). Making memories stick. *Scientific American*, 292(2), 74-81.
http://bit.ly/2heDemH

The main study of spaced learning by Kelley and Whatson. It covers the neuroscience that informs the method and describes three classroom studies and their results:
Kelley, P., & Whatson, T. (2013). Making long-term memories in minutes: a spaced learning pattern from memory research in education. *Frontiers in Human Neuroscience*, 7, 589.
ncbi.nlm.nih.gov/pmc/articles/PMC3782739/

Study in which adults memorised 120 novel faces through massed or spaced learning. Brain activity was recorded using functional MRI scans:
Xue, G., Mei, L., Chen, C., Lu, Z.-L., Poldrack, R., & Dong, Q. (2011). Spaced learning enhances subsequent recognition memory by reducing neural repetition suppression. *Journal of Cognitive Neuroscience*, 23(7), 1624-1633.
ncbi.nlm.nih.gov/pmc/articles/PMC3297428/

Learners making science

Volunteering to make science and act as a scientist

Potential impact: Medium
Timescale: Ongoing

Citizens need skills and knowledge to solve problems, evaluate evidence, and make sense of complex information. A strong understanding of STEM (Science, Technology, Engineering and Mathematics) topics can develop these. It can also address current demands for employees with STEM skills. When learners experience how science is made, they increase their subject knowledge and develop scientific skills. The experience can also contribute to their personal growth and help them to understand what it means to be a scientist. Participating in and contributing to citizen science activities is key. These activities can promote engagement with both social and natural sciences. They also scaffold understanding of the scientific method, critical thinking and reflection.

Experiencing science

We live in a world where people are asked to solve complex problems, collect and assess evidence from varied sources, and understand and use information from digital media. In the workplace, there is high demand for employees who have skills and knowledge in STEM areas: Science, Technology, Engineering, and Mathematics. This demand is not only relevant to STEM jobs but to nearly all jobs and positions. STEM education and jobs are no longer viewed as options for the few or for the 'gifted'. Engagement with STEM can develop critical thinking, teamwork skills, and civic engagement. It can also help people cope with the demands of daily life. Enabling learners to experience how science is made can enhance their content knowledge in science, develop scientific skills and contribute to their personal growth. It can also increase their understanding of what it means to be a scientist.

Citizen science

An increasingly popular activity that could support this growth and development is citizen science. In *Innovating Pedagogy* (2016) we described crowdsourcing as activities that involve members of the public giving and receiving information to solve problems, create content, vote for the best solutions, or raise funds. We also referred to citizen science as participation in scientific or research projects. Citizen science activities can take place online on platforms such as *Zooniverse*, which hosts some of the largest internet-based citizen science projects, or offline in a local area. Citizen science projects include:

- *Galaxy Zoo*: citizen scientists classify galaxies
- *iSpot*: citizen scientists identify living things such as birds, plants, and insects
- *Bioblitz* events: citizen scientists gather in a park to find and identify all the species in the area
- Activities hosted by schools. For example, pupils might check their local water for acidity, oxygen, temperature and cloudiness, and share the results on a world map.

Advances in technology such as smartphones and other mobile devices make the process of collecting and analysing data easy (see the section of this report on Big-data inquiry). The availability of these technologies has led to an increase in the number of citizen science projects available. It has also led to a new focus on young people and how their participation in citizen science programmes can help their learning and development.

Citizen science can equip young people with knowledge and skills required to do research and understand science. With appropriate support, they can collect rigorous datasets, share their findings with other people, and investigate complex social and ecological systems. Participation in citizen science programmes can contribute to conservation initiatives. It can also influence young people's beliefs about the environment, making them more aware. This means that citizen science has the potential to change how young people think and act in relation to their surroundings, the environment, and other people.

> "Citizen science has the potential to change how young people think and act in relation to their surroundings"

Learning activities that target young people and aim to bring the less interested ones closer to science are often developed in science museums. For example, the Natural History Museum in London offers citizen science projects that anyone can join as an enjoyable way to interact with nature. *Earthworm Watch* is one such project that runs every spring and autumn in the UK. It is an outdoor activity that asks people to measure soil properties and record earthworms in their garden or in a local green space. *Fossils Magnified* is another project. This one asks volunteers to help digitise fossils for use in scientific research.

Museums are great places for schools and families to engage with citizen science, bringing young people closer to science and helping them understand how scientists work. For example, young people can get to know what types of question scientists pose and why, how they find and collect information to answer their questions, and how they inform others about their work. Access to museums such as the Natural History Museum is free of charge allowing all people, no matter what their background, to interact with such activities and meet others with similar interests.

There are currently many inequalities and gaps between people when it comes to accessing and participating in science activities. Citizen science is a STEM activity that lowers the barriers and invites everyone to become involved in making meaningful science.

Designing citizen science projects

Some citizen science projects focus on how volunteers can make science or act as scientists. Others ask volunteers to follow a process, collect data and contribute to projects initiated by scientists. Platforms such as *nQuire-it* enable people to create their own citizen science projects. These projects are related to such topics as ecosystems, safety, weather, and wellbeing. Examples of *nQuire-it* projects are:

- Which lift has the fastest speed and where is it located? Participants use sensors in their phones to measure the acceleration of lifts and identify the fastest one.
- What is hate crime and how can it be reported? Participants report instances of hate crime they have experienced and how they reacted to it.
- How noisy are your surroundings? Participants capture noise and project it on a map with the aim of identifying noise levels in a specific area, neighbourhood, or school.

How to design and participate in large-scale citizen science experiments is the focus of a recent collaboration between the BBC and The Open University. Support will be given to people to do mass experiments and contribute data in many forms, including images, text, and sensor data. Mobile applications such as the *Spot-it* and *Sense-it* apps will be used to collect data such as acceleration and light intensity. This will enable both scientists and members of the public to create and run online projects, providing an entry point to citizen science.

The Sense-it app (available in Google Play) reads phone sensors and connects to the nQuire-it platform at www.nquire-it.org

During the last few years, citizen science has received a lot of attention. This is due to its potential to educate the public – including young people – support the development of skills needed for the workplace, and contribute to real science. It can be an experience that allows people to become familiar with the work of scientists and learn to make their own science. However, there are still challenges to be addressed. Learning to make science requires time and dedication to understand how scientists work and produce reliable research, how data is collected to be valid, and how 'real science' differs from pseudoscience.

The role of more knowledgeable others is important; teachers, guardians or scientists should act as those guiding, supporting and facilitating engagement with citizen science projects. These activities also need people who can instil enthusiasm for learning about scientific activities. More work is needed to understand how best to support members of the public when they develop their own projects online, and how offline projects should be designed to promote learning and bring change to how people think and interact with their surroundings.

Resources

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

Natural History Museum, London:
http://www.nhm.ac.uk/take-part/citizen-science.html

nQuire-it citizen inquiry platform and linked Sense-it Android app for collecting data from mobile device sensors:
www.nquire-it.org
http://bit.ly/1oGFpw0

Zooniverse – one of the largest platforms hosting citizen science projects:
https://www.zooniverse.org

Study of the benefits to young people of engaging in citizen science:
Ballard, H. L., Dixon, C. G., & Harris, E. M. (2017). Youth-focused citizen science: examining the role of environmental science learning and agency for conservation. *Biological Conservation*, 208, 65-75.
http://bit.ly/2hefPlq

Edited book that presents evidence about the processes and outcomes of learning as they have been studied in a range of citizen inquiry projects:
Herodotou, C., Sharples, M., & Scanlon, E. (2018). *Citizen Inquiry: Synthesising Science and Inquiry Learning*: Routledge.
http://bit.ly/2w4c4Fr

Systematic overview of citizen science projects:
Pocock, M. J., Tweddle, J. C., Savage, J., Robinson, L. D., & Roy, H. E. (2017). The diversity and evolution of ecological and environmental citizen science. *PloS One*, 12(4).
https://doi.org/10.1371/journal.pone.0172579

Report by the US Department of Education presenting ideas and recommendations for an innovative future in STEM education:
Tannenbaum, C. (2016). *STEM 2026: A Vision for Innovation in STEM Education*. US Department of Education: Office of Innovation and Improvement, Washington, DC.
http://bit.ly/2d0aGxt

Open textbooks

Adapting openly licensed textbooks

Potential impact: Medium
Timescale: Ongoing

The Open Educational Resources (OER) movement has been releasing educational content since 2001. This content is released with an open licence – usually a Creative Commons licence – that permits all aspects of reuse. This typically means that they can be reused, remixed, revised, redistributed, and retained. OER come in many different forms, but key to their definition is that anyone can freely take them, change them, and reuse them in education. A form of OER that has attracted interest, particularly in North America, is the open textbook. These books are released with an open licence so they can be modified and adapted by educators and students. The digital format is usually free, and the print version has a low cost.

Reducing textbook costs

The initial motivation for open textbooks was to address the high costs of these books in higher education, where they can account for a quarter of a student's expenses. This led to a number of projects, such as *OpenStax* and *BCcampus*. These produce books on subjects, such as Introductory Statistics, that attract high student numbers. The projects pay authors to create textbooks, which are then openly licensed.

Initial research focused on exploring whether open textbooks worked as well as traditional, purchased versions. This work demonstrated that student performance was as good, if not better, with open textbooks. Further studies have shown that there is no relationship between textbook cost and student performance. Combining figures on student performance and student savings has provided reliable measures for the success of OER. Such reliable measures have often been missing from past research.

These studies were important in establishing the basis for open textbooks to be adopted and removing objections on the grounds of quality. However, at first, most open textbooks were used in much the same way as existing ones. While there were savings for students, there was no change in pedagogy. Over time, secondary benefits related to teaching and learning have become apparent. There is some evidence that use of open textbooks has improved retention in courses. This is because, in the past, some students did not purchase a relevant textbook. This affected their confidence or even their ability when studying the associated course. Educators using open textbooks have reported that they now assume all students have the textbook when they start the course, and teach accordingly.

Open pedagogy

More recently, the focus has shifted to the more significant pedagogic opportunities that openly licensed resources present. David Wiley, an expert in open educational resources, argues that open pedagogy arises when educators make use of the '5Rs': reuse, remix, revise, redistribute, and retain. He defines open pedagogy as 'the set of teaching and learning practices only possible or practical in the context of the 5R permissions'. This definition makes a direct link between open pedagogy and OER, although others prefer a broader definition.

One example has been the introduction of open textbooks at Tidewater Community College, Virginia, as part of the *Z-degree program*. This initiative enables students to earn a degree with zero costs for textbooks. Here the use of open textbooks has led to a redesign of the curriculum, with educators adapting open textbooks to provide complete course content for students. This approach is similar to a distance-learning course that includes a complete set of resources, but it is delivered on campus with support. In the past, the cost of producing such material would have been prohibitively expensive for a college, but the use of OER has made this possible. These courses have seen increases in recruitment, retention, and pass rates.

Infographic from GW Libraries, setting out benefits of open textbooks from an institutional perspective.

More radically, open textbooks can challenge the established relationship between students and knowledge. The open textbook is adaptable. This means it is not a fixed, static resource but rather a dynamic one. Students can edit and amend an open textbook as part of their study. Researchers Robin DeRosa and Scott Robison claim that, 'by replacing a static textbook with one that is openly licensed, faculty have the opportunity to create a new relationship between learners and the information they access in the course.'

> "Knowledge is not fixed and static; it is an ongoing process involving learners"

DeRosa replaced a $100 textbook with an open one, made this available online on a *WordPress* site, and made students editors. This gave them the opportunity to amend the text, excerpt longer texts, add front matter to each chapter, provide discussion questions, and add interactive video. Long-time online instructor Laura Gibbs reversed this process, basing her course on the development and adaptation of an 'UnTextbook' constructed by students from openly available resources.

In cases where most textbooks present only the perspectives of the powerful and the conquerors, interaction with open textbooks provides a means to decolonise the curriculum. Multiple authors and multiple editors can lead to a greater diversity of perspectives in disciplines. This approach not only helps to give learners ownership of the curriculum, but it also shifts their attitude. Knowledge is not fixed and static; it is an ongoing process involving learners. This can be viewed as part of a broader move within open education towards 'open pedagogy', which emphasises open content as well as open, distributed practices, such as working together to edit an article.

A danger in this move to open pedagogy is highlighted in the next section of this report. Learners do not only need the ability to edit textbooks, they also require the skills that will enable them to do this in a way that enables them to present a variety of perspectives and to build knowledge together. They need to be able to make informed decisions about where to get information, which sources to trust, and how to respond to conflicting opinions. Without these skills, they risk being trapped in filter bubbles or being misled by unreliable sources.

Conclusions

The OER movement is well established, and open textbooks represent a form of OER that helps to resolve a specific problem, the prohibitively high cost of many textbooks. This has positive impacts for learners, including the immediate availability of textbooks for all who can access and download internet files. It is in the area of adaptation where there is the greatest potential for innovation in pedagogy, which requires the development of a new set of skills. The textbook still dominates many approaches to higher education, and open textbooks can change learners' relationship with these resources.

Resources

This chapter uses examples to illustrate the empowering potential of open pedagogy:
DeRosa, R., & Robison, S. (2017). From OER to open pedagogy: harnessing the power of open. In R. S. Jhangiani & R. Biswas-Diener (Eds.), *Open: The Philosophy and Practices that are Revolutionizing Education and Science* (pp. 115-124). London, UK: Ubiquity Press. License: CC-BY 4.0
www.ubiquitypress.com/site/chapters/10.5334/bbc.i/

Blog post reporting an interview with an educator who uses open textbooks:
Gibbs, L (2014). *The UnTextbook: an OER interview*
http://anatomy.lauragibbs.net/2014/09/the-un-textbook-oer-interview.html

Blog posts and responses that consider what it means to be open:
Groom, J. (2017). *I don't need permission to be open*
http://bavatuesdays.com/i-dont-need-permission-to-be-open

Examination of how much money students can save when open textbooks are used:
Hilton III, J. L., Robinson, T. J., Wiley, D., & Ackerman, J. D. (2014). Cost savings achieved in two semesters through the adoption of open educational resources. *The International Review of Research in Open and Distributed Learning*, 15(2).
http://www.irrodl.org/index.php/irrodl/article/view/1700

Research on cost savings:
Hilton III, J. (2016). Open educational resources and college textbook choices: a review of research on efficacy and perceptions. *Educational Technology Research and Development*, 64(4), 573-590.
https://link.springer.com/article/10.1007/s11423-016-9434-9

Detailed analysis of use and impact of BC Campus open textbooks:
Jhangiani, R. S., Pitt, R., Hendricks, C., Key, J., & Lalonde, C. (2016). *Exploring Faculty Use of Open Educational Resources at British Columbia Post-Secondary Institutions*.
http://bit.ly/2hep3l3

Making the case that open textbooks are as good as, if not better than, purchased ones:
Shafer, K. (2014) *The Critical Textbook*
http://www.digitalpedagogylab.com/hybridped/critical-textbook

Blog posts on the meaning of openness and open pedagogy:
Wiley, D. (2017). *How is open pedagogy different? / When opens collide*.
https://opencontent.org/blog/archives/4943
https://opencontent.org/blog/archives/4990

Introduction to the INTRO (increased tuition revenue through OER) model:
Wiley, D., Williams, L., DeMarte, D., & Hilton, J. (2016). The Tidewater Z-Degree and the INTRO model for sustaining OER adoption. *Education Policy Analysis Archives/Archivos Analíticos de Políticas Educativas*, 24.
http://epaa.asu.edu/ojs/article/view/1828

Navigating post-truth societies

Epistemic education for the 21st century

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

Post-truth was 2016's Word of the Year, according to Oxford Dictionaries. Fake news and information bubbles are not new but awareness of their impact on public opinion has increased. People need to be able to evaluate and share information responsibly. One response is to integrate these skills within the curriculum. However, this raises a series of questions: What does truth mean? How can we tell what is true? How can we know which sources to trust? The ways in which people think about such questions are called 'epistemic cognition'. Researchers have developed ways of promoting learners' epistemic cognition. These include promoting understanding of the nature of knowledge and justification as well as fostering abilities to assess the validity of claims and form sound arguments. One approach engages learners in activities that involve conflicting accounts. These provide opportunities to make learners aware of their assumptions about truth, justification, and understanding. They also help learners to develop strategies for evaluating and constructing knowledge.

Challenges of a post-truth world

The buzz around terms such as 'post-truth' and 'fake news' reflects an increasing anxiety about how new media are influencing the ways in which people make sense of the world. The internet has created unprecedented opportunities for individuals and groups to produce and share information. People no longer rely solely on traditional media and official sources for news. They are likely to follow events on various social networks, blogs, websites, and apps.

These developments have many positive effects. For example, blogs and Wikipedia have increased the amount, diversity, and currency of the information freely available. However, these changes have also created new challenges. These include:

- **How do we avoid fake news?** Unvetted information is hard to avoid. This makes it difficult to identify trustworthy sources and credible information.
- **How do we decide who is right?** When searching topics online, such as the effects of a new drug or a new diet, people often encounter conflicting information and advice, even from expert sources. Choosing among these can be hard.
- **How do we burst the filter bubble?** Search engines and social media show people information based on their personal habits and preferences. People also tend to select information that matches their existing opinions. This creates information 'bubbles' that can reinforce biases and prevent people from learning about alternative viewpoints.

> “People make daily decisions about where to get information, which sources to trust, and how to respond to conflicting information”

Whether or not we explicitly think about these issues, we make daily decisions about where to get information, which sources to trust, and how to respond to conflicting information. These decisions reflect our assumptions about which kinds of knowledge are worth having, who is trustworthy, how to evaluate information, and more. The ways in which we think about such issues are called 'epistemic cognition'.

What is epistemic cognition?

Epistemic cognition is thinking that is concerned with knowledge and how people know. Researchers in this area examine how people acquire and justify knowledge, as well as how they understand the nature of this knowledge. According to educational psychologist Clark Chinn, epistemic cognition is not only concerned with achieving knowledge but also with goals such as developing scientific models and gaining understanding. What these goals have in common is that they are all concerned with representing the world in some way.

Chinn and his colleagues developed the *AIR model of epistemic cognition*. According to this model, epistemic cognition has three components:

1. **Epistemic Aims and Value** – goals and values that drive cognition and action. These include wanting to know, seeking the truth, and avoiding error.
2. **Epistemic Ideals** – criteria or norms that people use to decide whether they have achieved their epistemic aims. These ideals can also be used to evaluate other people's epistemic products, such as arguments and websites.
3. **Reliable Epistemic Processes** – processes and strategies that enable the achievement of epistemic aims. Reliable processes are ones that are likely to result in a successful outcome. Even though truth is hard to achieve, a reliable process is more likely than other processes to get to the truth.

These three components can help explain what goes on when people search the internet for information.

Applying the *AIR model* to online searching: an illustration

Epistemic Aims and Value – A teenager investigates websites about the safety of mobile phone use because she wants to *find out the truth* about whether using her mobile phone is safe. This goal has *practical value* for her because she wants to stay healthy.

Epistemic Ideals – She initially believes that good explanations are those that are easily *understandable*. As she encounters more and more conflicting information about mobile phones, she realises that good explanations should be *based on evidence* and should be published by *trustworthy experts*.

Reliable Epistemic Processes – She initially thinks that it is best to rely on the first site that appears on the Google results page. Later, she realises that a more reliable process is to *compare and contrast multiple trustworthy sources of information*.

What is epistemic education?

Studies have shown that, if it is not specifically addressed, epistemic cognition develops slowly and gradually. Many people avoid dealing meaningfully with the complex information in the world around them by adopting one of two approaches.

The first approach is to take the view that there is only one truth: 'we are right and they are wrong'. This means finding the truth by relying on the authorities endorsed by our social group. People taking this approach are likely to avoid examining alternative explanations or arguments with an open mind.

The second approach is to give up on finding out the truth and instead to choose what seems 'right for me'. This approach avoids critical examination of explanations or arguments and may result in hasty conclusions.

Such challenges have prompted the development of epistemic education – instructional efforts to promote learners' epistemic growth. These efforts vary greatly, but they often take a two-pronged approach:

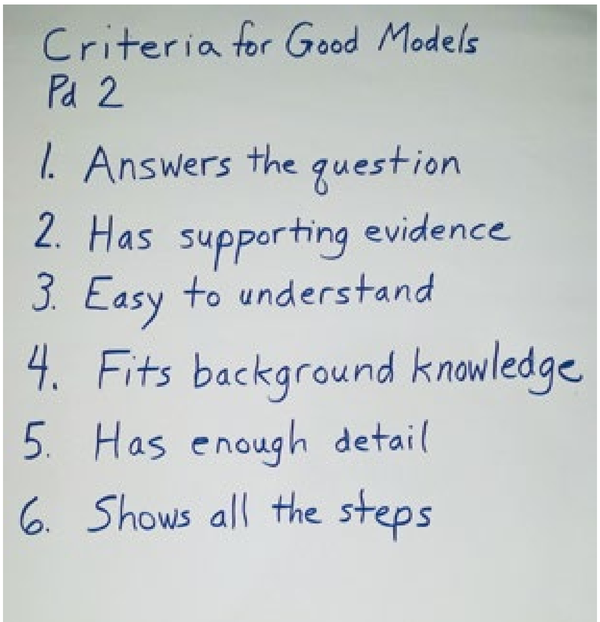
1. They seek to develop learners' awareness that knowledge is complex, diverse, developing, constructed within particular perspectives, and informed by particular sources of evidence.
2. They also aim to foster an appreciation that alternative explanations or arguments are not equally right or valid, that some ways of knowing are better than others, and that knowledge can be reasonably critiqued and evaluated.

Ways of promoting epistemic growth

How can such challenging goals be achieved? Several design principles have emerged from work to promote learners' epistemic growth:

Expose learners to the diversity of knowledge. Learners are used to textbooks that present a single authoritative account. This does not prepare them well for engaging with post-truth societies or for advanced learning. Instead, in epistemic education, learners engage with multiple accounts and sources. For example, in History education, they engage with primary and secondary documents that present contrasting viewpoints. In Science education, they engage with competing scientific models or arguments and explore various sources of evidence. Importantly, these information sources expose students to the rich informational complexity that is typical of online environments.

Support the development of epistemic criteria. Learners can be helped to develop epistemic criteria or norms for evaluating the diverse explanations, arguments, and websites that they encounter during their studies. One approach, often used in studies that aim to promote website evaluation, is to provide learners with information about important evaluation criteria and with guidelines for applying these criteria. Learners can also develop epistemic criteria on their own. For example, in the *PRACCIS* project (illustrated below), students discuss and develop lists of epistemic criteria for evaluating scientific evidence and scientific models, which they then apply using checklists.



Student list of epistemic criteria for evaluating scientific models from the PRACCIS (Promoting Reasoning and Conceptual Change in Science) project.

Support the development of reliable processes and strategies for making sense of the world. Learners can benefit from learning to engage in reliable epistemic processes and strategies. For example, in studies conducted by the Stanford History Education Group, learners learn the techniques that historians use when reading historical documents. Teachers model these strategies and provide organisers to help learners apply them. Researcher Julie Coiro and her colleagues developed an online inquiry tool for exploring controversial issues on the internet. The tool helps learners to identify arguments for and against an issue and to critically evaluate and synthesise information from multiple sources.

Encourage learners to reflect on their assumptions. Epistemic cognition is often implicit and learners may be unaware of the assumptions that guide them. Scaffolding epistemic criteria and processes can provide them with practical evaluation tools, but may not provide opportunities for thinking critically about epistemic issues. Metacognitive prompts, such as, ‘How do you know?’ or ‘How did you evaluate this website?’ can encourage learners to reflect on their assumptions and uncover the criteria and processes they used. These discussions provide opportunities for reflecting on which epistemic criteria and processes are important, why they are important, and how to apply them. Teachers can also engage learners in discussing the epistemic criteria and processes that appear to have been used (or not) in the production and validation of the information they encounter online.

Motivate learners to care about truth and knowledge. Critical evaluation of information, weighing conflicting accounts, and reading arguments and viewpoints outside your own ‘information bubble’ are difficult and time-consuming activities. One of the biggest challenges facing epistemic education is motivating learners to care about epistemic aims and to persevere in achieving them. Some inspiration can be drawn from work on fostering learners’ ‘intellectual virtues’. For example, philosopher Jason Baehr worked with teachers to develop practices for fostering nine intellectual virtues: curiosity, intellectual humility, intellectual autonomy, attentiveness, intellectual courage, intellectual thoroughness, intellectual carefulness, open-mindedness and intellectual tenacity. These practices include drawing attention to the value and meaning of intellectual activities, modelling intellectual virtues, giving learners opportunities to practise virtues, and providing feedback on learners’ virtues.

Resources

Guide for evaluating information on social media:
Caulfield, M. A. (2017). Web Literacy for Student Fact-Checkers.
https://webliteracy.pressbooks.com/

In this video, Clark Chinn talks about epistemic design and creating learning environments to foster epistemic growth:
http://bit.ly/2elEyxi

Philosopher Jason Baehr’s website on Educating for Intellectual Virtues:
http://intellectualvirtues.org/

Materials from the PRACCIS project – promoting reasoning and conceptual change in science:
http://www.praccis.org/

The *Reading Like a Historian* curriculum by the Stanford History Education Group offers resources for developing critical reading and thinking skills:
https://sheg.stanford.edu/rlh

Introduction to the field of epistemic cognition, including a section that reviews epistemic cognition interventions:
Greene, J. A., Sandoval, W. A., & Bråten, I. (2016). *Handbook of Epistemic Cognition*: Routledge.
http://bit.ly/2xcMlyG

Online tool for exploring controversial issues on the internet:
Kiili, C., Coiro, J., & Hämäläinen, J. (2016). An online inquiry tool to support the exploration of controversial issues on the internet. *Journal of Literacy and Technology,* 17, 31-52.
http://bit.ly/2wKy6y0

How an elementary school teacher fostered epistemic norms in her class by engaging students in scientific argumentation:
Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education*, 96(3), 488-526.

Intergroup empathy

Understanding the perspectives of others

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

Online environments such as social media form global virtual spaces. In these, people from different backgrounds interact with each other, even if they come from countries or cultures that are engaged in conflict. This means that skills such as communication, teamwork, and empathy are important for constructive participation. When conflicting groups are kept apart, they are likely to develop negative stereotypes of each other. These stereotypes are associated with prejudice, hostility, and aggression. Members of groups that do not have opportunities for constructive social contact may think in terms of 'us' versus 'them'. This perspective increases anxiety and makes it difficult to empathise – to understand and share the feelings of members of the other group. The effects of intergroup conflicts can spill over into online communities, provoking strong negative emotions and the use of stereotypes. In such cases, activities designed to promote intergroup empathy can provide effective responses and help to reduce tensions.

FEEL: fostering empathy through e-learning

Empathy is a network of psychological processes that allow one person to know, feel, and understand the internal states of another person, and respond accordingly. *Foster Empathy through E-Learning (FEEL)* is an approach based on the understanding that developing empathy in group members is key to improving relations between groups of people. Appropriate pedagogical strategies in online environments can be used to develop intergroup empathy. They support the development of empathy in three areas:

Empathic Resonance: a spontaneous, emotional mirroring of another's experiences, such as pain or joy. It is often intuitive and unconscious.

Empathic Reasoning: a conscious effort to imagine yourself in the place of another.

Empathic Response: involves being motivated to act in an appropriate way to address another's needs.

Under the right conditions, direct, carefully planned contact between groups can improve intergroup relations. Supporting the development of intergroup empathy is key to the success of such efforts. Some skills and knowledge help people develop a more positive outlook towards other groups. These include:

- gaining accurate knowledge about the other group
- correcting wrongly held beliefs and stereotypes
- overcoming anxieties about the other group
- reducing feelings that the other group is a threat
- re-humanising the other group
- realising a common, unifying human identity
- developing an ability to judge the merit of different perspectives and narratives.

When face-to-face contact is not possible, extended forms of contact can be put in place in technology-rich environments. Though many of these strategies were not designed specifically for educational purposes, they can be adapted and incorporated into diverse learning environments.

One example is the *Humans of New York (HONY)* project. This features a blog that introduces street portraits and interviews by the site's author, and has more than 20 million followers on *Facebook* and *Instagram*.

This is not a formal learning environment – it provides online contact, with viewers offering their responses to images and stories. They are encouraged to share similar or contrasting experiences, and moderators monitor the discussion to make sure that comments are not used to attack the subjects. *HONY* shows that this approach can promote constructive contact between people with various cultural backgrounds. A study of the project found many expressions of empathic resonance, reasoning, and response in the comments and discussions.

In another example, Jewish Israelis used virtual reality to engage in conversations about a sensitive conflict issue with a virtual Palestinian character. The character, *Jamil*, spoke with a positive tone of voice. The program monitored the body movements of the human taking part in the conversation, and made sure that Jamil moved in the same way (mirroring). The tone and movement were designed to elicit empathy as Jamil described the difficulties of Palestinians' lives. A study showed that this extended contact with a virtual member of another group resulted in more empathic reasoning and response to Palestinian suffering.

> “Role playing helps participants to think in different ways and to look at issues from a new angle”

Extending the approach of the previous example, *The Enemy* project enables people to use virtual reality to meet someone from an enemy group. Equipped with virtual-reality glasses, participants enter a room where they meet 3D virtual images of combatants from three conflict zones (El Salvador, Congo, and Israel-Palestine). The images are based on real videoed interviews with the combatants, who share testimonies and confessions about their lives, experiences, and perspectives. The virtual encounter allows viewers a first-time direct experience of 'the enemy'. The experience is intensified by the direct eye contact that the simulated characters maintain with viewers. This powerful experience can lead people to consider a previously unexamined view of the conflict and to engage in empathic resonance and reasoning.

Designing for intergroup empathy

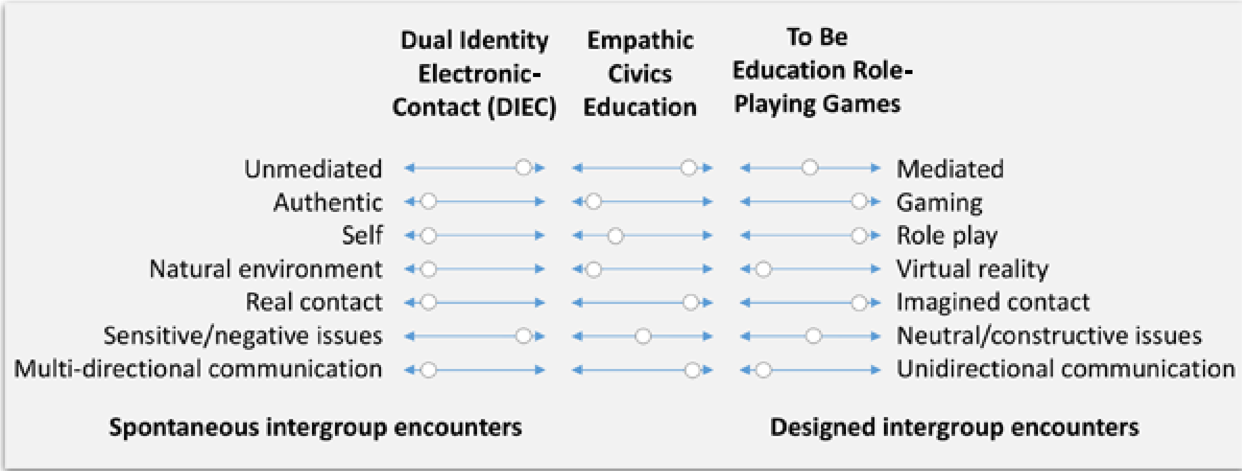
When designing educational environments to promote intergroup empathy, there are several elements to consider.

- **Mediation** helps people to overcome negative feelings and encourages them to participate in a constructive way.
- **Gamification** helps to overcome anxiety about interacting with other groups by introducing a non-threatening virtual context.
- **Role playing** helps participants to think in different ways and to look at issues from a new angle.
- **Virtual reality** provides controlled simulations that can offer challenging encounters in a safe environment.
- **Imagined contact** can take place using a variety of different media and is useful when face-to-face contact is difficult.
- **Neutral or constructive issues** provide a focus that helps participants to avoid potentially explosive situations.
- **Mode of communication** can be adapted depending on how ready the participants are to engage in a dialogue.

As the image below shows, these different elements can be represented as sliders, like the ones in an audio mixer that is used to set the sound profile for a piece of music. Without intervention, all sliders will tend to be on the left side. This setting represents individuals dealing directly with sensitive or negative issues in their authentic natural environment, experiencing real and unmediated intergroup contact. A situation like this may lead to nonproductive or even explosive encounters between members of different groups. The examples described below feature various *FEEL* profiles that move away from this situation. They show how *FEEL* profiles can be used as a design tool in environments that have been developed for educational purposes.

The Dual Identity Electronic-Contact (DIEC) project involves Muslim and Christian high school students from segregated religious schools in Australia. Groups of four (two from each religious group) worked online together towards a common goal of developing an environmentally sustainable future for Australia. This involved eight internet chat sessions, each lasting 50 minutes, within the framework of a carefully planned curriculum. These activities led to a reduction in intergroup bias among participants. The *FEEL* profile on the left of the image above shows that the programme was highly mediated (supported by a structured curriculum) and involved authentic contact in a natural learning environment, as opposed to virtual reality. It engaged participants in two-way communication about constructive social issues, helping them to work to achieve a common goal.

Another encouraging example is the *Empathic Civics Education* project. This project used a popular television series that depicts the lives of Arabs in Israel with humour and compassion, in a manner that is not often accessible to the Jewish majority group. Jewish teachers and students engaged in a series of related activities. These included guided viewing of short online video clips and sharing their experiences in an online community. The *FEEL* profile for this project is shown in the middle of the image above. It features high levels of mediation via the designed activities mentored by the facilitator, and an imagined contact with the fictional characters of the television series. Communication with these characters was indirect, enabling participants to reflect on the clips in a supported and protected environment. The teachers and students who took part in the project significantly enhanced their understanding of and empathy towards the Arab minority in Israel.



Foster Empathy through E-Learning (FEEL) profiles of educational programmes.

There are also platforms that enable educators to use gaming technology to develop learning environments for students. One that is good for fostering intergroup empathy is *To Be Education*. Teachers and students can easily use this platform to develop short role-playing games. Students are randomly assigned a character and use this to debate and make decisions regarding various issues. They do this using a chat window, and resources chosen in advance with the help of information about each of the characters. A mentor can also take part in various parts of the chat. Games designed by teachers and students include dozens that refer to various intergroup relations. The *FEEL* profile in such games –

shown on the right of the image on the previous page – involves a high level of gaming, role play, and imagined contact via the fictional characters.

Our networked society creates new challenges by bringing together people from different and sometimes conflicting groups. It also offers a wealth of technologies that can support innovative pedagogies to improve intergroup relations. The *FEEL* framework offers a way of thinking about design considerations. It helps teachers and developers to adapt learning environments to specific needs and constraints. It is important to remember, however, that this is only a starting point. Further developments to the framework will support the development of more educational projects to foster intergroup empathy.

***To Be Education*: a platform for designing and playing role-playing games.**

Resources

The Enemy project website:
http://theenemyishere.org

The Enemy video trailer:
https://www.youtube.com/watch?v=zG0w_l-o4ks

Humans of New York website and Facebook page:
http://www.humansofnewyork.com
https://www.facebook.com/humansofnewyork

To Be Education, an online platform that allows the development of creativity and innovation skills:
http://www.to-be-education.com/

Examination of a professional development programme designed to support Civics teachers in their efforts to promote empathy among different groups:
Shapira, N., Kupermintz, H., & Kali, Y. (2016). Design principles for promoting intergroup empathy in online environments. *Interdisciplinary Journal of e-Skills and Lifelong Learning*, 12, 225-246.
https://www.informingscience.org/Publications/3605

Immersive learning

Intensifying learning by experiencing new situations

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

Immersive experiences transport us to another place, giving us a feeling of being in the heat of the action and having some control over what happens next. Reading an interactive novel is one such experience. Readers can choose how the action in the story will continue or what the characters will do. They may even be able to enter the story as one of the characters and get involved in the action. Using this approach, immersive learning allows people to experience a situation as if they were there, using their knowledge and resources to solve a problem or practise a skill. The learning is intensified by bringing in vision, sound, movement, spatial awareness, and touch. Participation in immersive learning is likely to be stimulating and memorable.

Technologies and designs for immersive learning

Traditionally, immersion requires people to act out scenarios or take part in activities, with actors and props to simulate reality. Nowadays, playing a video game on a smartphone or watching sports on a virtual reality headset are designed to be immersive, interactive experiences. Students can use technologies such as smartphones, 3D computer screens, large displays, headsets or helmets with screens inside, and gloves fitted with sensors. These enable them to experience immersive learning in a classroom, in a museum, in a work setting, at home, or outdoors.

Basic technology such as phone text messages can be used to send people to real or virtual locations, creating a feeling of partial immersion, but immersive learning often involves augmented reality (AR) or virtual reality (VR). With AR, learners can look at the world through special glasses or a handheld device such as a smartphone and see labels, images, 3D shapes, characters, or animations added to the view. This can be part of a game, a puzzle, a trail, or any kind of exploration of the environment. AR has recently become very popular thanks to the *Pokémon Go* game on smartphones. In the game, players create avatars (representations of themselves) that interact with artificially generated creatures and buildings that appear in their surroundings.

> “Immersive learning experiences can be playful, engaging and compelling”

In VR, learners can become avatars interacting with other avatars. They can travel through time and space. They can play ‘what if?’, by exploring possibilities that cannot be set up in real life. They can engage in activities that would be difficult, dangerous or impossible in everyday life. Game elements are often involved.

Examples from various disciplines

Immersive learning can improve education in a variety of disciplines. For example, it can be effective in Medicine and Healthcare training. Medical students can practise surgical skills or talking to virtual patients. Student nurses can practise caring for casualties in an emergency scenario. Dentists can learn to control a drilling tool. Learning in an immersive virtual environment makes it possible to carry out repetitive training and internalisation of medical procedures without endangering actual patients. It is also sometimes seen as a helpful solution in situations where healthcare educators have reached their capacity to handle an increasing number of students.

Cultural Heritage and Tourism education have also adopted immersive learning. Architectural and natural heritage awareness games offer realistic reconstructions of real locations and sites to help learners appreciate and learn about their features or values. Immersive treasure hunt games draw attention to cultural points of interest. In History, participation in a battle re-enactment can mean learners moving around a room with their mobile devices displaying different views of a battle scene and possible actions. This can lead to greater involvement and understanding. Augmented reality can also be used to superimpose images from the past onto present-day locations.

In language learning, students can be exposed to situations in which they communicate in the target language, interacting with native speakers, other learners or avatars. Learning situations constructed in 3D virtual worlds offer realistic scenarios that enable language learners to practise their language skills in a variety of contexts without the need for physical travel. In Science and Technology, a ‘real’ crime scene can be used to engage young people in applying knowledge gained in the classroom.

Pros and cons of immersive learning with technology

Immersive learning can promote active participation and deeper engagement. These can increase the quality of group discussion and improve understanding. An important advantage is the chance to practise real-world skills in a safe environment, repeatedly, avoiding potential harm to real people and damage to equipment or property. The multimedia and multisensory elements can reinforce learning and make it more appealing and memorable. On the other hand, immersive learning makes use of technologies that require some technical competency or

A University of Nottingham geology student uses immersive virtual reality on a field trip to see how the landscape around him looked during the last Ice Age.

literacy. The equipment and software can be expensive, although the use of smartphones is more affordable than large 3D displays or head-mounted equipment.

Conclusions

Immersive learning is based on the experience of being transported to another place or environment. This can be achieved in a variety of ways. It is well suited to learning that relates to a specific context or situation and involves trying out and practising particular skills and strategies. Immersive learning experiences can be playful, engaging, and compelling. They may enable more students to be taught or trained. They can also support those who have fallen behind with their studies or need more practice. Immersive learning can combine use of advanced technology with conventional teaching methods such as role play and field work.

Resources

Overview of immersive learning for teachers
Burns, M. (2012). Immersive learning for teacher professional development. *eLearn*, 2012(4), 1.
http://elearnmag.acm.org/featured.cfm?aid=2181208

Gary Priestnall used immersive virtual reality with Geology students on field trips to see how the landscape looked during the last Ice Age (pictured on previous page).
http://bit.ly/2w4Bhzq
http://oro.open.ac.uk/29887/1/

Blog post that provides an introduction to virtual reality and learning:
Jagannathan, S. (2017). *Virtual reality: the future of immersive learning for development*
http://bit.ly/2zQwBP9

Immersive learning and dental education:
Dutã, M., Amariei, C. I., Bogdan, C. M., Popovici, D. M., Ionescu, N., & Nuca, C. I. (2011). An overview of virtual and augmented reality in dental education. *Journal of Oral Health and Dental Management*, 10, 42-49.
http://bit.ly/2hfq2l1

Augmented reality and language learning:
Godwin-Jones, R. (2016). Augmented reality and language learning: from annotated vocabulary to place-based mobile games. *Language Learning & Technology*, 20(3), 9-19.
http://llt.msu.edu/issues/october2016/emerging.pdf

Student-led analytics

Using data to help learners set and achieve their own goals

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

In the last decade, learning analytics have helped institutions, teachers, and policy makers to understand student learning and outcomes. These analytics make use of the data generated during study activity in order to enhance learning and teaching. They often focus on how teachers and institutions can help learners to pass a test, a module, or a degree. Last year's *Innovating Pedagogy* report encouraged a move away from a focus on assessing what has been learned and towards helping students to learn. Student-led learning analytics enable learners to specify their own goals and ambitions. They also support learners to reach these goals. This is particularly helpful for individuals who have little time to spare for study.

Learner goals and motivations

Learners often have goals that relate to their own interests. They may want to explore a phenomenon from their own perspective – 'What impact is global warming having on my region?' or 'Is my house likely to be flooded as sea levels rise?' They may just want to answer a single question, such as, 'Do wasps do anything useful?' For curious learners like these, finding the answer to a complex question will provide a successful learning outcome and experience. They are likely to have less interest in whether they complete a module or qualification successfully.

Other learners are interested in conventional markers of academic success. Their interest in grades does not necessarily reflect an interest in the content of their course. They may be aiming to get the grades necessary to attend a reputable school or university. Their ultimate goal may not relate to the course they are studying but rather to the job it will help them to obtain. Some learners may want to be top of the class, whatever the topic. Others will want to pass their module with the minimum effort, in order to finish a particular learning unit or complete a particular degree. Some will be interested by a subject but struggle to pass because they are bored by the work they are set.

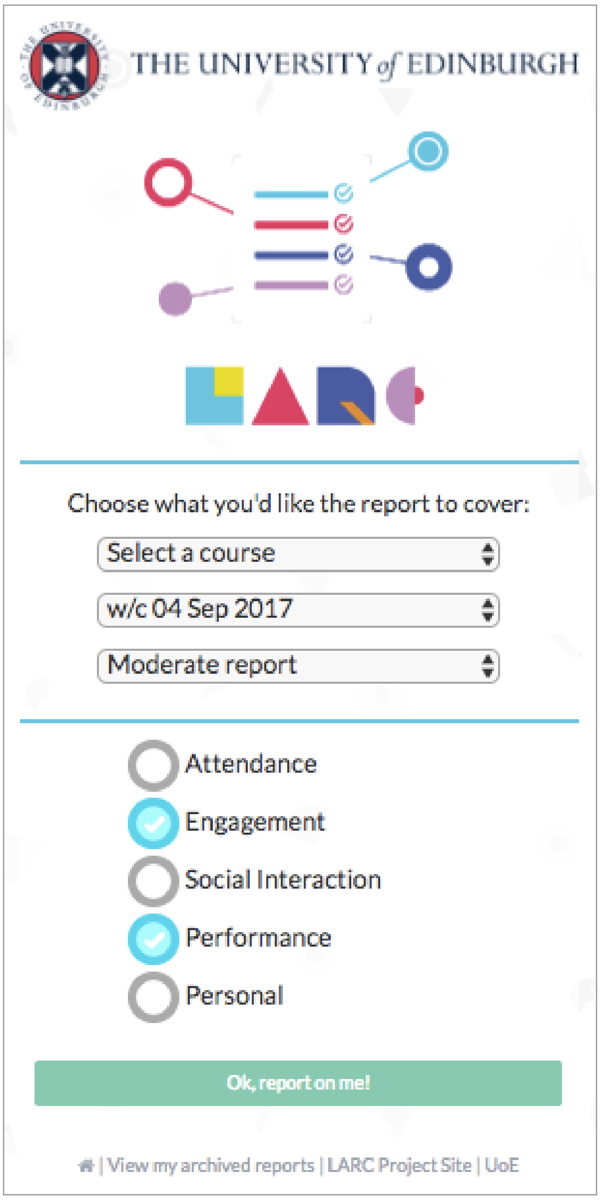
This range of motivations and study patterns means that both institutional analytics focused on grades and learning analytics that predict student outcomes based on previous behaviour and engagement may wrongly identify which learners are at risk. They may also fail to encourage others who want to be pushed to the limit. The scenarios above are not unusual. What is interesting about them is that students do not often make these types of motivation explicit to teachers. So, which analytics could be used to help students to achieve their ambitions in a certain period of study?

Helping students achieve their ambitions

A range of tools has been employed at the University of Michigan to help students who are experiencing academic difficulties. Two of these, *Grade Calculator* and *Get Things Done*, can be considered to be student-led analytics. *GPA Calculator* enables students to estimate their grades based on current and future performance. This makes it easier for learners to decide whether it is safe to coast or whether they need to work harder to match their learning goals. *Get Things Done* provides a weekly checklist developed by a teacher. It suggests tasks that students should complete to prepare for their classes. This checklist allows students to make decisions about how much time they want to spend on these activities and how much effort they intend to put into achieving grades.

Putting learners in control

Student-led analytics put learners in control. They can select their own goals and ambitions and then choose which learning analytics they want to review in order to achieve those goals. An early form of student-led learning analytics is the *eCoach* at the University of Michigan. This enables students to set their own goals for the week and receive tailored learning analytics advice. Based on historical data and performance of students of similar ability, *eCoach* can provide specific advice for students who want to move from a B to an A grade, as well as for those who want to pass with minimum effort and receive a C grade.



The *Learning Analytics Report Card (LARC)* interface.

> “Student-led analytics put learners in control”

The University of Edinburgh provides an experimental example of student-led analytics, the *Learning Analytics Report Card (LARC)*. This project produces various data that can be included in text reports. Students choose which data to include and when to produce the report. They then review their own data. The main categories they can select are: Attendance, Engagement, Social Interaction, Performance and Personal. These report cards give students opportunities to reflect on their performance and to decide where to put their effort as the course progresses. They are therefore able to make decisions based on data rather than simply on their own perceptions of progress.

Recent research on attitudes to learning and Mathematics performance at Maastricht University has revealed a complex picture. Some students do really well when faced with complex mathematics, while others struggle even when they receive substantial predictive learning analytics feedback. In part, this is because most current learning analytics applications cannot distinguish between behaviour and cognition and because they do not take into account the underlying attitudes of students. For example, an Economics student who has previously been successful but is now experiencing a lot of anxiety for reasons unrelated to the course may find it stressful to receive feedback. In such a situation, even the best feedback on Economics problems might prove to be counter-productive. The option to shift goals and priorities, or to receive feedback on study skills, could provide much better support.

More advanced forms of student-led analytics will not only take into consideration learners’ goals and ambitions and offer personalised learning analytics solutions. They will also allow learners to rate and share how appropriate and relevant these student-led analytics are for their personal goals. These ratings would automatically be shared with relevant peers.

This would be comparable to *Strava*. This app for athletes enables cyclists and runners to develop new routes, share training plans, and comment on riders' performances and chosen routes.

Student-led analytics give individuals the power to create and share their own learning journeys and benefit from each other's experiences. These analytics applications would benefit from charting the behaviour and cognition of learners. They would also make peer group recommendations available. For example, learners might rate their learning materials as useful, fun, exciting, difficult, irrelevant, boring, or engaging. Such ratings would help students to benefit from the experience of others while, at the same time, trying to uncover new and individual paths forward.

Student-led learning analytics allow learners to share their goals with teachers. They provide opportunities to discuss how these goals might be reached, or adjusted, as priorities shift. Unlike previous learning analytics applications that are focussed on learning goals set by teachers, student-led analytics allow individuals to identify their own learning goals and use these to develop their own routes to success.

Resources

A suite of tools at the University of Michigan, showing how students and teachers can make use of (student-led) analytics:
http://ai.umich.edu/portfolio/academic-reporting-tools

Learning Analytics Report Card (LARC):
http://larc-project.com/

Design and implementation of the *Learning Analytics Report Card (LARC)*:
Knox, J. (2017). Playing with student data: the Learning Analytics Report Card (LARC). *Practitioner Track Proceedings of the 7th International Learning Analytics & Knowledge Conference (LAK17)*.
http://bit.ly/lak17-practitioner-track

Making the links between students' dispositions towards learning, behaviour and learning analytics predictions. The abstract and introduction to this paper are openly available:
Tempelaar, D. T., Rienties, B., & Nguyen, Q. (2017). Towards actionable learning analytics using dispositions. *IEEE Transactions on Learning Technologies*, 1 (Jan-March 2017), 6-16.
http://ieeexplore.ieee.org/document/7839177/

Big-data inquiry: thinking with data

Understanding the world by working with large sets of data

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

New forms of data, data visualisation and human interaction with data are changing radically and rapidly. As a result, what it means to be data literate is also changing. In the big data era, people should not simply be passive recipients of data-based reports. They need to become active data explorers who can plan for, acquire, manage, analyse, and infer from data. The goal is to use data to describe the world and answer puzzling questions with the help of data analysis tools and visualisations. There is a growing demand for data literacy in all disciplines and for data analysts in all sorts of industries and organisations. Understanding big data and its powers and limitations is important to active citizenship and to the prosperity of democratic societies. Today's students therefore need to learn to work and think with data from an early age, so they are prepared for the data-driven society in which they live.

Big data

How is big data different and why is it so challenging to handle? Big data includes many variables. It is wildly large, has no obvious organisation and is unwieldy and unruly. Some people would define it as a dataset too big to be handled by typical spreadsheet software such as *Microsoft Excel*. A particular challenge is that most big data was not collected in order to address a problem of interest to us; it is simply a set of data that looks as though it might be relevant to our problem. We therefore have to try to reconstruct what this data is and why, how and where it was collected. This allows us to answer questions such as, 'How trustworthy is the evidence that this data provides?' Revealing the creation process of big data is important when estimating and justifying the extent to which we can generalise from patterns in the data to populations or processes that we care about.

Surprisingly, with big data people can easily draw false conclusions and are more likely to believe them. Why? Lots of patterns can easily be found in big data, but these may just be a result of the way the data was assembled rather than facts about some aspect of the world in which we are interested. With big data, the conclusions come from huge amounts of data and from technology that is unfamiliar to most people. This makes those conclusions seem more convincing and makes it hard for us to become sceptical or critical. As data scientist Cathy O'Neil says, 'Big data doesn't eliminate bias, we're just camouflaging it with technology.' For example, when algorithms are given the job of sorting and rejecting job applications, this can lead to unintended discrimination against certain groups.

Students therefore need to keep in mind that relying on bad information can lead to false conclusions and bad decisions. Even when they have access to data that appears to be 'good' and 'clean', it will still reflect biases. Data and algorithms reduce a complex reality to a simpler view of the world. Only the parts of the world that are easily measurable can be used and these measurements can be misleading when taken out of context. In addition, learners need to be aware of their preconceived ideas about the subjects they are studying and be willing to change or update those ideas.

To prepare learners for these big data challenges, researchers and educators in statistics education and other fields have started to rethink the ways in which we teach data education at all age levels. Big data education is in its infancy and is just beginning to consider some of the following questions: (a) What are the characteristics of big data inquiry tasks (how do they differ from small data tasks)? (b) What is it important to learn about big data from an early age? (c) Which computational tools can scaffold the learning of big data?

Big data tasks

Data education is highly experiential; it is a practised art and a developed skill. Students need to encounter purposeful project-based, real-world applications with real data to build their conceptual understanding. For example, the *Common Online Data Analysis Platform (CODAP)* is a tool that can be used by students to explore real data. It enables them to generate different visualisations of their data both simply and quickly, encouraging them to follow their curiosity.

Statistics teacher Tim Erickson recently offered three ingredients of typical big data tasks: being awash with data, data moves, and data properties. Being 'awash with data' brings up the image of a stormy sea of data. The inquiry situation is usually non-standard, and therefore ripe for creativity and ingenuity. The best direction is often unclear. It is easy to be confused by the data, not knowing what it means and where it comes from. The task is to find order in chaos and signal in noisy data.

In big-data inquiry tasks, students should be involved in 'data moves'. These include: integrating data from various sources and cleaning it, reorganising the data, making new or unusual visualisations, defining new variables and designing new measures, slicing, filtering, or otherwise choosing cases. For example, given the data as first presented, a pattern cannot be seen, but by choosing a subset intelligently, a pattern emerges.

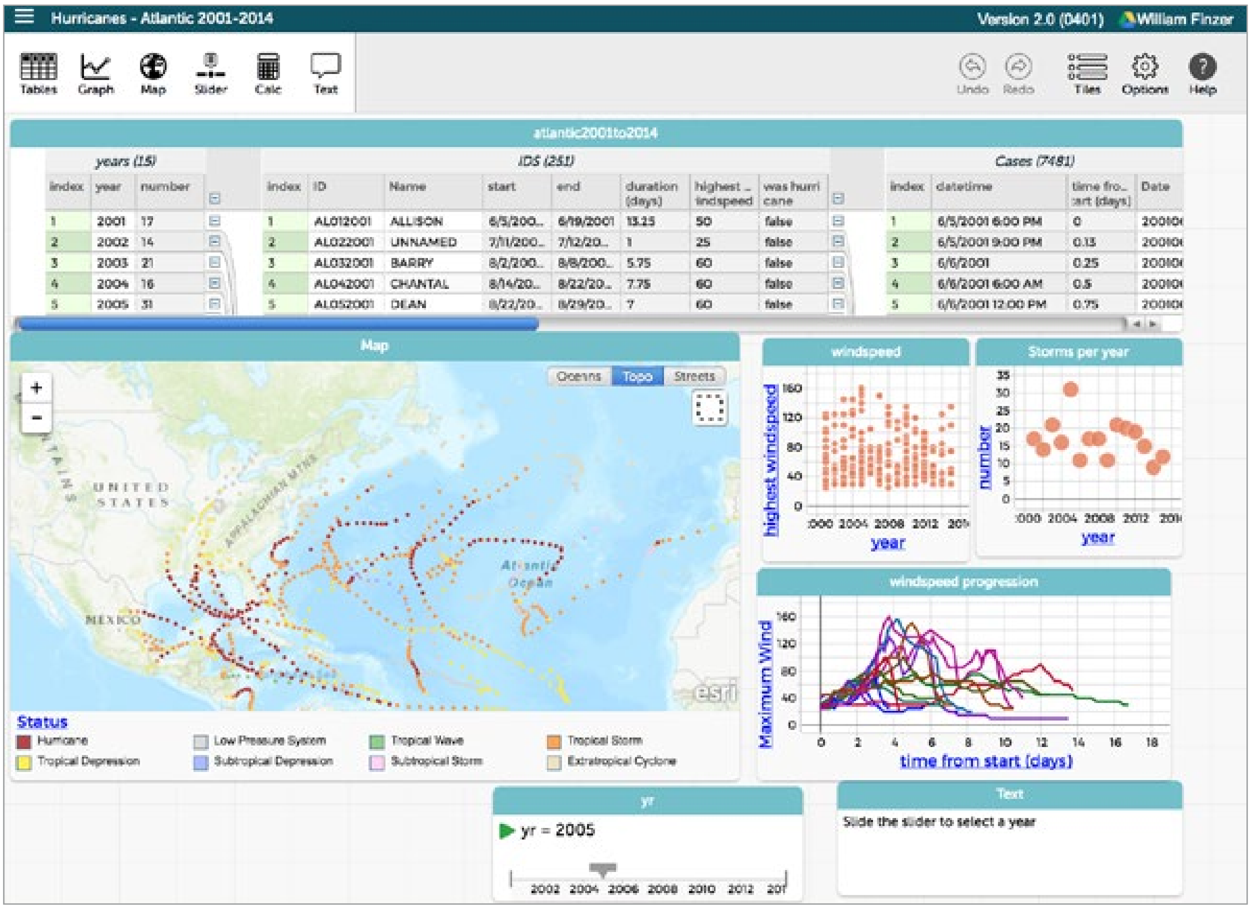
The *Ocean Tracks* project provides a large dataset that tracks the paths of animals living in the Pacific Ocean. These data can be visualised on maps, in tables, and in graphs. *Inquiry Space* enabled students to visualise data generated by their own inquiries or by simulations. Students using the *Ocean Tracks* interface can study the ways that marine animals migrate across the Pacific Ocean, and how those movements are shaped by the environment around them.

Big data education

The Statistics education community has made encouraging progress in emphasising that early experiences with data should focus on foundational statistical ideas. These include understanding distribution, variability, sampling, and statistical inference. More generally, they include authentic and purposeful inquiry with data. The data cycle of obtaining, wrangling, curating, managing and processing data, exploring that data, defining questions, performing analyses, formulating inferences, and communicating the results is the core of data education experience.

What does the emergence of big data have to offer for data education? With technology appearing in every aspect of life, and the growing availability of big datasets, goals for students should focus more on conceptual understanding and attainment of data literacy and less on learning a separate set of tools and procedures. Today, most of the procedures in data analysis are handled by software. This enables learners to concentrate on planning an investigation, creating and interpreting data representations, building models, and making decisions. Over time, any particular procedural function can be expected to be taken over by software. It follows that the biggest need for every student is to develop a conceptual understanding of data and chance.

Many suggestions have been made about developing the highly needed conceptual understanding of big data, beyond the current emphasis on authentic data-based inquiry approaches. One option is to move data education away from its traditional focus on testing the significance of findings and to engage students as early as possible in sound modelling practices. This will develop their ability to interrogate, assess and revise statistical models at all levels. A statistical



Hurricane data structured by year, including measured positions of each hurricane, in CODAP. The user controls which data and graphs are shown on the map.

model provides a simple description of a process that may have produced the observed data, explaining why it varies as it does.

One advantage of modelling-based pedagogy is that data modelling provides a way to link data, chance, and context together to develop key statistical ideas. Technological innovations in simulation, visualisation and handling of big data have enabled students to address complex problems, even at a young age. Beyond access to problems, the focus on purpose, shareability, and re-use of statistical models generates new opportunities for generalisation and invention of statistical tools and representations, with a focus on practices and processes.

By focusing on modelling processes rather than on the model itself, the modeller becomes the designer, drawing on a rich repertoire of experiences, mediated by technological tools, peers and their own explanations. These developments provide new stimulus for growth in rethinking the role of statistical modelling in helping students to develop statistical reasoning and to interact with data, context, and chance.

Students need to experience purposeful data modelling inquiries using both data they have created and data they have collected, structured, and cleaned. Too often, students are set to engage with datasets that can provide clear answers to fairly simple questions. However, tasks for young students should focus on creativity, ingenuity, and uncertainty, working in settings where their datasets are surprising, disruptive, and need to be modelled in creative and flexible ways.

Study of big data education is inherently interdisciplinary. Working with data requires mastery of a variety of skills and concepts, including many traditionally associated with the fields of Statistics, Computer Science, and Mathematics. A student must be prepared to work with the data commonly found in workplaces and research labs. For example, accessing and organising data in databases, scraping data from websites, processing text into data that can be analysed, and ensuring secure and confidential data storage. These all require extensive computing skills. Simple tools have been designed to allow students to engage creatively in open-ended computational spaces, inventing approaches and solutions to interesting problems. The educational emphasis needs to be on cultivating conceptual understanding rather than on learning to carry out mechanistic computation.

Big data tools

New exploratory data analysis tools, such as *CODAP* (educational) and *Tableau* (commercial), create interactive environments that help people see and understand their big data. These data analysis tools can be used to encourage exploration, play, and puzzlement.

> “ Data analysis tools can be used to encourage exploration, play, and puzzlement ”

CODAP is a free, open-source, web-based data tool designed as a platform for developers and as an application for students at secondary level and above. Data can be dropped into the platform from the internet. Alternatively, a simulation or game that generates data can be embedded. Default graphs scatter data points randomly until data from tables is dragged to assign horizontal and vertical axes. Representations link dynamically across tables, graphs, and maps. *CODAP* can be incorporated across the curriculum to help students explore and learn from data from any content area and advance their skills to use data as evidence to support a claim.

Moving forward

Teaching students to be fluent in working and thinking with big data could result in profoundly different classrooms, more engaged and creative students, and more successful outcomes. Big data education offers the opportunity to capture the imagination of children and adults, by designing opportunities for students to develop innovative approaches to data creation, representation, measuring, modelling, and inference. Although some of the tools now available make it easy to pull in and visualise data, students will need support in interpreting their data and understanding their visualisations. They will also need to learn how they can use data to investigate problems and how to justify their claims with reference to multiple datasets and repeated measurements.

Resources

Blog post that considers what data science is and how to teach it:
Erickson, T. (2017). *Smelling like data science*.
https://bestcase.wordpress.com/2017/02/21/smelling-like-data-science

Text and video introducing the *Common Online Data Analysis Platform* and showing it in use in schools:
http://www.oceansofdata.org/projects/common-online-data-analysis-platform-codap

The *Ocean Tracks* interface was designed to enable students to develop questions, plan and carry out investigations, and analyse and interpret data:
http://oceantracks.org/about
http://oceantracks.org/map/

This article from *The Guardian* newspaper introduces some of the main themes of Cathy O'Neil's book, referenced below, which deals with the harmful effects of algorithms:
Weapons of Math Destruction: Cathy O'Neil adds up the damage of algorithms
http://bit.ly/2eYuH4o

Tableau is a commercial data tool that enables paying customers to use visual analytics for data exploration:
https://www.tableau.com

Using *Ocean Tracks* with students to investigate marine migration:
Busey, A., Krumhansl, R., Mueller-Northcott, J., Louie, J., Kochevar, R., Krumhansl, K., & Zetterlind, V. (2015). Harvesting a sea of data: using authentic data to investigate marine migrations. *The Science Teacher*, 82(5), 44-49.
ltd.edc.org/sites/ltd.edc.org/files/Article.pdf

Guidelines for courses in data science:
De Veaux, R. D., Agarwal, M., Averett, M., Baumer, B. S., Bray, A., Bressoud, T. C., Bryant, L., Cheng, L. Z., Francis, A. Gould, R. et al. (2017). Curriculum guidelines for undergraduate programs in data science. *Annual Review of Statistics and Its Application*, 4, 15-30.
http://bit.ly/2lqW7rT

Consideration of the ways of thinking, questioning, and problem-solving that learners can develop as they work with data:
Finzer, W. (2013). The data science education dilemma. *Technology Innovations in Statistics Education*, 7(2).
http://escholarship.org/uc/item/7gv0q9dc

O'Neil, C. (2017). *Weapons of Math Destruction*: *How Big Data Increases Inequality and Threatens Democracy*. New York, NY: Crown Publishing Group.

What will it mean to be statistically literate in the next decade?
Wild, C. J. (2017). Statistical literacy as the earth moves. *Statistics Education Research Journal*, 16(1), 31-37.
http://bit.ly/2ifMeso

Learning with internal values

Using students' interests to inspire learning

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

Well-being in our networked society is related to our ability to learn and use technology as a resource for learning. We all navigate our learning according to our own needs and interests. We may want to learn the skills necessary for a new job, make an informed choice when we go to vote, find out which vaccinations our children should receive, or how to use a new piece of software. Throughout life, significant learning is triggered, monitored, and owned by us as individuals. Interest groups and learning communities help us to achieve our goals. This learning is rooted in our own needs and interests and shaped by our internal values. When learning is based on our internal values, we take ownership of our learning and are willing to put in the effort needed to learn.

Helping learners achieve their goals

Developing a learning culture that helps learners manage their learning and achieve their own objectives seems to be an obvious goal for education from early childhood onwards. However, it is difficult to achieve. There is a tension between what students want to learn, and what the educational system dictates they should learn. A school that must teach a national curriculum has to conform to a set of external values. These are unlikely to align exactly with learning that is based on individual students' internal values.

Efforts have been made to design and develop programmes that can meet this challenge. The main approach offers students choice about what and how they learn. At the same time, it equips them with means to develop appropriate knowledge, skills, and ways of thinking in order to support their learning. This approach balances the learning based on students' internal values with the learning that is required and the normative values of the educational system.

In past decades, these educational programmes began to make use of their social context. They supported productive interactions between students, using these to support learner choice and autonomy. Recent developments in technology have made this integration of interaction easier to achieve. Artificial intelligence supports greater interaction with content. Networking platforms support greater interaction with other people. New learning environments include these forms of interaction. They have the potential to promote learning that is based on learners' internal values while equipping them with knowledge and competencies they will need as lifelong learners in a networked society.

Supporting choice in a social context

Providing students with the freedom to choose what and how they prefer to study can increase students' sense of ownership of the learning process. They are less likely to feel that they are participating in a process owned by the teacher or the educational system. This freedom can also address the diversity of interests in any classroom. Research shows that 'less can be more' when the breadth of content is reduced, allowing students to dig deeper into smaller portions of the content.

For instance, in an undergraduate introductory course in Biology, students were provided with online resources such as lecture recordings and interactive visualisations. These resources supported independent study of ten major course topics. Students were asked to choose one topic to study in more depth, as part of a learning community that specialised in this aspect of the course. Students received support with this process and with the online content. They also met to present and discuss their topic with peers and the course instructor. Students in each of these communities were able to consider core principles in Biology, such as the relationship between form and function.

Their in-depth learning in the community that dealt with a specific subject enabled students to develop deeper understanding of the other topics, which they studied on their own. When compared with students who took the same course but were taught via lectures, there were several differences. Students who had made their own choices were less likely to focus only on finding the right answers for the final test. They were more likely to seek personal growth, make efforts to learn, negotiate meaning with peers, and take ownership of their own learning process.

Many learning environments use technology to enable students to choose what they study according to their own interests, allowing them to devise their own learning paths. Such environments may support students to develop internal values while independently navigating their learning. However, a trade-off is that one of the greatest assets of learning in school may be lost – the opportunity to discuss and negotiate with peers in the struggle to develop deep understanding of complex ideas. Learning environments that integrate the two are promising, especially when they foster students' sense of responsibility regarding not only their own learning, but also their peers' learning.

For example, a platform called *Knowledge Forum* supports students in devising their own learning paths. They can choose which content they will study. As they do this, they are also committed to advance the knowledge that is gradually being developed within the community of their classmates. The online platform provides a shared environment for communication that supports textual and graphical representation of student ideas as notes. Students can reorganise these notes, negotiate and advance the community's collective knowledge. The platform is designed to encourage students to take responsibility for advancing the class's knowledge. The annotation tool means students can give each other feedback. They can also write 'rise-above' notes that bring together the ideas in sets of related notes contributed by different students. This tool has been used with many age groups. Research shows that the choice and independence it provides, together with the commitment to advance the collective knowledge of the community, often result in deeper and more sustained inquiry.

Supporting autonomous learning in a social context

There have been many attempts to provide learners with tools that enable them to make choices about what they value as they advance through a given curriculum. The aim is to balance autonomy (supporting learning based on students' internal values) with rigour (making sure that their learning is in line with ideas that have been tested and accepted by society). This aim has driven the development of various educational technologies. Early efforts resulted in 'teaching machines'. These devices introduced students to up-to-date educational content. They provided immediate and automatic feedback on multiple-choice questions. With an emphasis on positive reinforcement, these machines enabled learners of various ages to advance at their own pace, thus helping them to take charge of their own learning. However, learning is a complex process. Simply structuring curriculum materials and providing positive reinforcement did not provide enough support. Multiple-choice questions provided a very limited way of assessing understanding.

Work to provide automatic support for students to achieve their goals has led to the development of student-led analytics (see page 29). Another approach is open learner models. A computer compares the key knowledge and skills in a subject area with the knowledge and skills that a learner has demonstrated and produces a representation – an open learner model – of the learner's progress. The learner can reflect on this representation, produce evidence to challenge it, or use it to decide what to work on next. This approach requires the creation of a detailed description of the subject area, and of how knowledge and skills build upon each other. These descriptions are time-consuming and difficult to create, but good progress has been made with developing them in areas of Mathematics and Science.

> “ When learning is based on our internal values, we take ownership of our learning ”

Alongside these advances in automated guidance, which enable learning to be personalised, the social aspect of learning has gained renewed attention. For example, many massive open online courses (MOOCs) augment their automated guidance with peer-review activities. When these are designed and implemented well, they provide human feedback on complex activities that artificial intelligence still cannot assess. They can also provide learners with a sense of community and responsibility for their peers' learning.

Recently, promising new technology-enhanced educational models have been developed to support autonomous learning within the social context of the classroom. *Knowledge Community and Inquiry (KCI)* is an approach that combines automated guidance with support for learning in a knowledge-building community. As with *Knowledge Forum*, students use content aggregators to add to, edit, and link content. They can create a community knowledge base, and use social media techniques to negotiate knowledge within the community. Students' interaction with this knowledge base is automatically assessed, so individual learning paths can be aligned within the community.

In one *KCI* learning environment, students studied a wall-sized simulation of evolutionary processes within a rainforest. Each student recorded their own observations on a tablet computer and shared these with fellow students. A visualisation of the aggregated knowledge was created automatically. This was displayed in real time on a smartboard, to guide students as they continued to explore the simulation.

EvoRoom collective immersive simulation of evolutionary processes within a rainforest.

Studies that have implemented the *KCI* approach in various contexts have produced promising findings. Pupils at middle and high school developed integrated understanding of complex topics such as the physiological and environmental causes of asthma. They also developed students' internal values for learning.

These approaches use technology to provide students with greater opportunities to choose how and what they learn. Technology also provides tools to support autonomous learning. Individuals whose learning is aligned with their internal values often do not learn alone. Meaningful interactions with their peers are an important part of the process. Such innovations help to equip students with the knowledge, competencies, and ways of thinking required for their well-being as citizens of a networked society.

Resources

EvoRoom – an immersive, room-sized simulation of a rainforest ecosystem:
https://encorelab.org/2014/01/evoroom/

Knowledge Forum – an electronic group workspace designed to support the process of knowledge building:
http://www.knowledgeforum.com/

Reforming an introductory Biology course:
https://sites.google.com/site/biology1technion

The *Web-based Inquiry Science Environment (WISE)* – a research-based digital learning platform:
https://wise.berkeley.edu/

Study of a Science module, showing its potential to support students' internal values:
Ben-Horin, H., Pion, C., & Kali, Y. (2016). Designing technology to foster socioscientific reasoning by promoting internal values of learning. Paper presented at the *12th Chais Conference for the Study of Innovation and Learning Technologies: Learning in the Technological Era*, The Open University of Israel.
www.openu.ac.il/innovation/chais2017/f1_2.pdf

This paper reports a three-year study designed to encourage students to assume increasing levels of collective responsibility for advancing their knowledge of optics:
Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge-building communities *Journal of the Learning Sciences*, 18(1), 7-44.
http://bit.ly/2fEvBWs

Humanistic knowledge-building communities

Helping learners to develop knowledge

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

The goal of humanistic education is to help people become open to experience, highly creative, and self-directed. This is a person-centred approach. On the other hand, knowledge-building communities aim to advance the collective knowledge of a community. This is an idea-centred approach. When the two approaches are combined, they create a new one: humanistic knowledge-building communities (HKBCs). Research shows that students who participate in these develop their knowledge and selves in integrated and transformative ways.

Person-centred approach

The humanistic movement, with its person-centred approach, emerged in full force during the American cultural revolution of the 1960s. More than any other scholar, Carl Rogers can be credited with articulating the key educational ideas and implications of this perspective, particularly in his book, *Freedom To Learn*. At its core, person-centredness is concerned with developing 'fully functioning' people – those who are open to experience, highly creative, and self-directed. To help people get on the path towards lifelong personal growth, Rogers laid out some key principles:

- prizing the individual
- listening carefully and empathically
- giving people the freedom to explore their self-interests, motivations, strengths, and weaknesses.

One of the major developments that came out of person-centred thinking is the encounter group. These groups met, often with a trained leader, to increase self awareness and change behaviour. Common variations of this idea can be seen in activities such as ice-breakers and team-building activities. Many modern organisations incorporate elements of this person-centred approach, supporting individuals to realise their talents.

Idea-centred approach

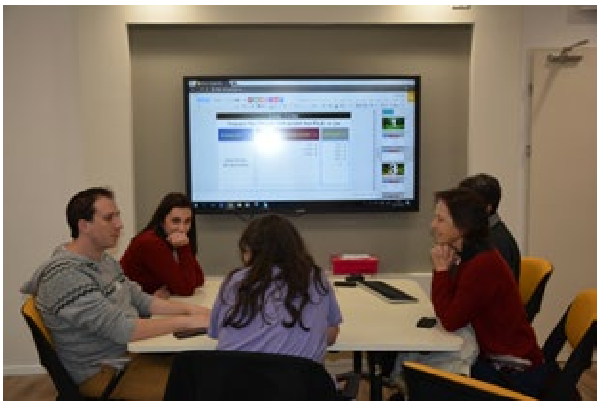
Idea-centredness is a more recent innovation. In the early 1990s, two educational researchers in Canada, Carl Bereiter and Marlene Scardamalia, articulated the theory of knowledge-building communities. Their motivation was to support authentic learning. They had observed that the culture of schools is often far removed from what disciplinary experts actually do. Knowledge-building communities in classrooms were developed to simulate the authentic types of activity and practice that real knowledge workers carry out.

For example, to make scientific discoveries, researchers working on their own problems need to build on or rise above existing ideas. So, in classrooms, ideas are at the centre of collective efforts. Using innovative technologies, such as the *Knowledge Forum* tool for group work, students can read and build on other students' contributions while working on problems that they find interesting. This pioneering theory and design have now spread across the globe, impacting schools across five continents and inspiring nation- and system-wide educational reform, such as in Singapore.

When participants enter an idea- or person-centred group or community, they are prompted to focus on either knowledge or on the self. Idea-centredness focuses on advancing community knowledge as participants share the experiences of working together. The participants' selves may be important, but the idea-centred activities are not focused on the individuals. In contrast, person-centredness draws attention to the self by proposing activities that get participants to reflect on their experiences and who they are. While knowledge may be important, it is only a secondary concern in these designs.

Uniting the approaches

Humanistic knowledge-building communities (HKBCs) bring together these two approaches. The belief underlying HKBCs is that person- and idea-centredness can co-exist and that they work together in exciting new ways. A design that integrates idea- and person-centredness targets two complementary goals that are linked by the shared experiences of the members in the learning community. As students develop knowledge, they must also consider their own personal interests and practices as learners; as they consider themselves, they are guided by the new knowledge they advance.



Graduate students in an HKBC reflect on themselves as learners in relation to the collective knowledge goals.

This two-centred theory of HKBCs guides how they are applied in practice, whether this occurs in physical classrooms where students meet face-to-face, in online environments, or in hybrid classes. For example, students in a physical classroom can divide their time between encounter group meetings (person-centred approach) and activities that advance their knowledge, such as doing independent research or having group meetings to discuss big questions (idea-centred approach). As students understand more about themselves, they are more able to explore knowledge-based questions on topics that interest them.

> “As students develop knowledge, they must also consider their own personal interests and practices”

For example, in a class of secondary-level students studying the human body, one student came to understand that the way he played around with contraptions to catch animals at home was related to the mechanical views of important bodily systems that he was formulating in the class. He could see how his 'self-as-an-engineer' influenced his knowledge about the body, freeing him either to advance these views or to step out of them to try different perspectives.

The Knowledge Forum

Online, the theory of HKBCs has important implications. The *Knowledge Forum*, a web-based collaborative learning platform developed to help students advance their collective ideas, is a popular knowledge-building innovation. The forum has functionality that helps students build knowledge, using notes that are coloured to indicate whether a person has read (and is therefore aware of) others' contributions, and directional arrows that make connections between people's ideas.

A person-centred perspective adds new types of use to the *Knowledge Forum*. In addition to knowledge building, personal and community-oriented spaces can be designed to help students become fully functioning members of the community. In personal spaces, students manage their own pages (views) on the *Knowledge Forum*. Here they can write reflective diaries about their experiences and discuss these with their peers. In community spaces, students can have discussions about the collaborative challenges they face, which strategies can be used to overcome them, and what makes for a good contribution. They can also make social announcements. By understanding learning as a combination of person- and idea-centredness, important insights about how to design and use educational technologies in innovative ways have been made.

Research has explored the use of HKBCs in both K-12 schools and higher education in several subject areas. The results point to transformative effects, including adult students who are already in the prime of their career reconsidering and changing some of their lifelong learning habits. In a world where students have opportunities for customised and self-directed learning, but also need to learn authentic disciplinary practices, HKBCs offer an important way forward.

Resources

Empirical articles on the theory and practice of HKBCs by its founders:
Rogers, C. R. (1969). *Freedom To Learn: A View of What Education Might Become*. Merrill Publishing Company.
Openly accessible summary by C. J. Weibell of 'Freedom to Learn':
http://bit.ly/2f9b5No

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, 3(3), 265-283.
http://bit.ly/2xjibsf

List of resources about knowledge building and the Knowledge Forum:
http://bit.ly/2wQCTgu

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