Knowledge Building as a future focus pedagogy in science classes

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Introduction

This paper is intended to initiate discussion on how Knowledge Building could be an effective pedagogy for framing future-oriented education in science classes. Knowledge Building is a model developed by Scardamalia and Berieter (2003) to support students to be knowledge creators. Knowledge Building may be defined simply as the creating, testing and improvement of conceptual artefact, it is not confined to education but applies to creative knowledge work of all kinds (Scardamalia, 2002). Educators have long been advocating that young people will not be prepared to face the social, political, economic, health and environmental challenges in today's society and indeed the future (Collins & Halverson, 2010; Facer, 2011; Gilbert, 2005). It is argued that there should be opportunities for students to be able to not only share knowledge but invent new knowledge (Lai, 2014). Moje (2008) contends that students' understanding of how knowledge is created is perhaps as important as knowledge itself. Pellegrino and Hilton (2012) view 21st century skills as knowledge that can be transferred or applied in new situations. This transferable knowledge includes both conceptual knowledge within the explanatory domain of a discipline and also epistemic knowledge of how to apply knowledge in order to construct new knowledge. Where emphasis is placed on creating new solutions, new methods to solve problems rather than applying previously learned actions to solve new problems. Conventional teaching and learning centring on transmissive, routine, and reception of existing knowledge, will no longer be adequate in preparing our students to tackle multifarious and interconnected problems. Future-focussed pedagogies in science education should focus on supporting students to be innovative, explorative, and capable of building knowledge collaboratively as a class community or even further, as a community of classes. Consequently, future science education is charged with the responsibility to devise and develop pedagogies to increase young people's innovative capacity in order to meet the challenges of current times.

The Knowledge Building model stands out from inquiry learning and problem-based learning practices sometimes seen in science or modern learning environment programmes. On the surface, some of the features are similar to inquiry learning, and teachers can have difficulty in distinguishing between these two approaches. The Knowledge Building model goes further, to support students to go beyond sharing and reproducing knowledge. Lai (2014) maintains that the goal of Knowledge Building is to create new ideas and public knowledge communally. It builds a suite of student perspectives, gathering ideas and questions from all. There is an intentional phase of idea improvement, where students have opportunity to develop and create ideas. In this specific pedagogy, the students are supported to contribute their ideas as a community. A digital space is implemented into the learning and teaching programme to support the developing inquiry, where students post their ideas. Knowledge Forum, Moodle or Padlet web-based software have been designed and modified to support Knowledge Building using a set of scaffolding tools. Students can show their classmates their science inquiry over the entire course of lessons and to disclose new ideas created as they proceed in the topic. There is also opportunity for Knowledge Building classes from different schools to work on the same science inquiry, and potentially, whole school involvement to be developed across curriculum areas.

Young people as knowledge creators

Knowledge Building is a pedagogical model described by 12 principles (see appendix) developed by Scardamalia and Bereiter (2010). One of those clearly illustrates that ideas are improvable, able to be improved, and the setting is for young people to have the opportunity to perform this improvement practise as a community, rather than as individuals. Students take control of the inquiry, they are given autonomy to set, plan, have goals, engage in creating further questions and responses. It allows students to take over a significant portion of the responsibility for their own learning including planning, execution and evaluation. Another hallmark of the Knowledge Building model is that it makes an important distinction between learning and knowledge creation. For Bereiter and Scardamalia (2010), Knowledge Building is a means for students to create and develop communal ideas, however, it will also deepen individual understanding of content knowledge and help students become self-directed learners. Learning is seen as a personal, internal, cognitive process of knowledge representation for individuals, whereas

Knowledge Building is an external progression of producing ideas, and where students collectively create and improve ideas, ideas are being treated as external, public artefacts (Lai, 2014). Gilbert (2017) reinforces the case that young people can be knowledge creators. She signals Knowledge Building does not focus on how disciplinary knowledge is constructed by experts, nor is it personal construction of content knowledge. Conversely, it provides a sense of autonomy for students to operate in a space between those concepts of personal construction and disciplinary knowledge.

Future-oriented capacities

An intention of future-oriented science education is developing knowledge with learners which considers implications for a human and potentially non-human society (Kurzweil, 2005). Scientific and future technologies come packaged with a variety of moral, political, ethical and indeed practical decisions. Future oriented examples could include: artificial intelligence, natural disaster relief, space travel, human genetic modification, synthetic life, nuclear fusion and renewable energies. Hodson (2010) urges the value of explicitly featuring socio-political contexts in science teaching programmes. If current social and environmental problems are to be solved, we need future generations of scientifically and ethically literate citizens. As science teachers we can place prominence on using topics of personal and societal issues. This takes a much more future-oriented direction to help foster learner capabilities of personal construction using these topics of interest. My viewpoint, is that personal knowledge of socio-political contexts is an active, participatory practice, where learners construct ideas together, where they can make sense of different viewpoints, grapple with conflicting arguments and justify them. The Knowledge Building model develops these specific learner capacities of manipulating knowledge, and working collectively to create and improve ideas.

The other important aspect of a future oriented capacity is for students to be encouraged to be responsible for other student's science learning. The Knowledge Building model does this specifically in terms of all student viewpoints are considered through community (see appendix, principle 2). Students can take roles in the inquiries, working in teams in the class with specific duties such as technician, researcher and director. They can support each other in the way they learn, using these roles.

Could Knowledge Building be used to support students studying science?

A purpose of studying science defended in the New Zealand Curriculum (Ministry of Education, 2007), is for students “to use their current scientific knowledge and skills for problem solving and developing further knowledge” (MOE, 2007, p.28). Students determining what information is valid and reliable is a necessary part of becoming informed. Authentic scientific inquiry depends on making decisions about whether information is justifiable and posing questions to establish its validity (Barker, 2011). Students could use questions such as: How could we critique this evidence? How could we redesign this investigation to ensure we have not overlooked any issues that may compromise our findings? Scardamalia and Bereiter (2014) argue that Knowledge Building actively supports learners to have agency or the capacity to act and make decisions about knowledge. This principle of Knowledge Building titled *epistemic agency* (see appendix, principle 6), is where students have responsibility for the knowledge that they are investigating. This learner capacity to have awareness of and to have insight into the development of knowledge appears to be critical in both Nature of Science and Building Knowledge ideologies.

In terms of Knowledge Building and learning, Scardamalia and Bereiter (2014) are very clear that they are not the same (see Gilbert, 2017). Students involved in a Knowledge Building science class can obviously experience learning while knowledge creation is taking place, however the emphasis is not placed on learners individually, but working collectively. This is a key distinction. Whereas in terms of Nature of Science (NoS) and Knowledge Building, they have overlapping considerations. Incorporating a collaborative digital space such as Knowledge Forum in a Knowledge Building class students can promote sharing of both science declarative knowledge as well as scientific inquiry practices. Students working together as a community draw together different conceptual knowledge that they bring to an inquiry, and subsequently their viewpoints about the investigations maybe distinctive. This allows students to explore data and investigations differently and in a fuller fashion than if one person were investigating. In addition, through sharing ideas in smaller teams, students can recognise the tentative NoS, because they may hear one of their classmates interpreting an idea in a different way.

Small scale studies such as Goh, Chai and Tsai (2012) have found that secondary science students' views on NoS improved with a Knowledge Building programme in Singapore schools. Students in the research were found to have increased levels of critically evaluating knowledge from a range of sources like their teachers, their peers and text books. A collaborative Knowledge Building research project in Hong Kong promoting both scientific processes and science achievement (Chan, Lam & Leung, 2012) investigated 15-16-year-old chemistry students. Measures such as the extent to which the students elaborated and built on their classmates' postings, questions and ideas that most enhanced their scientific understanding. It was demonstrated that, when engaged in Knowledge Building discourse, students had opportunities to articulate their views and to examine their own understanding with regard to others' models, thus helping them to develop epistemic agency. In another study closer to home, Lai (2014) explored a Knowledge Building community model with senior students in New Zealand distance biology and physics classes. As in Chan, Lam & Leung (2012) results show how Knowledge Building was an effective pedagogy to develop student epistemic agency. Three categories of epistemic actions were identified: identifying knowledge gaps; sharing of individual ideas and information; and creating communal ideas. It was evident that students felt the benefits of self-directed learning and learning in a communal digital space.

When studying science, students come to appreciate the differences between observation (using the senses) and inference (why it happens), this cognitive process, specific to Nature of Science, involves constructing understanding by making inferences from the observed data (Lederman & Lederman, 2004). How these ideas are interpreted depends much on students' beliefs and individual backgrounds. One of the 12 Knowledge Building principles developed by Scardamalia (2002) aligns well with the Nature of Science, where ideas are improvable (able to be improved) and there is purpose to create knowledge useful to the community. This principle associates closely with the process of observation and inference, that is the encouragement of students to generate explanation-driven questions (the "how" and "why" questions). *Real ideas and authentic problems* (see appendix) are specific to the Knowledge Building principle concerned with learner understanding based on problems and/or observations in the real world. This establishes the need for students to work on developing the questions, rather than just sharing information. As well as asking "what" questions, some subtle, careful remodelling can be prompted: “What makes you think so?” “How do you know that?” What science ideas does your explanation link to?” The justification of ideas using explanations to these questions gives rise to opportunities where new knowledge could be espoused; hence the role of the teacher plays a crucial role in supporting the students to facilitate the nature of these specific questions pertinent to NoS. To sum up the links between NoS and Knowledge Building, Barker (2011) invites a thought-provoking question “What do students actually have to know about the NoS?” (p.34). The response lies in that they begin to perceive that the world is understandable, through the interchange of observation and inference their own understanding evolves, explanations require specialist language, and where they have agency to make decisions about the validity of knowledge.

What could it look like in science classes?

Knowledge Building involves students using an inquiry progression of scaffolding and building ideas together as a class community (Scardamalia & Bereiter, 2010). The Knowledge Building community model developed by Lai (2014) requires specific pedagogy that supports movement between analogue and digital experiences. Students are viewed as knowledge creators where they have experience of reality, present in the classroom space, integrated with a set of digital affordances or possibilities offered by digital tools such as software programmes: Padlet, Moodle and Knowledge Forum. Prominence is placed on sharing questions and ideas collectively, using digital software. They draw on their experiences and are given opportunity through a digital mechanism to be able to communicate these. Initially the method usually involves a start-up question and associated background information, posed by a teacher or student, to evoke interest in a topic. The virtual discussion space is called a “view”, and “notes” are posted by the students in the class, to develop a collective noticeboard which displays the posted notes to all. With support from the teacher students can arrange the posted notes into themes, they can refute claims and also acknowledge ideas from their peers. The view page simultaneously captures the questions and these are displayed from all members of the class. There is opportunity for small teams of students to collaborate together and consider specific sub-topics, developing side investigations to enable to respond to questions which they have been identified as significant. Other stages of the Knowledge Forum/Padlet/Moodle process are where students pose their own theories, they make notes, identify what they need to understand, and take the opportunity using the digital medium to improve on the knowledge. Stages are communicated and viewed on specific pages of the software used. At these stages, students read literature, construct models, search the internet for information, consult their teacher/s, discuss their ideas with community experts, and conduct practical tasks. Students can use the thinking prompts available or develop their own to support theory building or progressive problem solving.

Conclusion

Knowledge Building is a model that has considerable opportunity for further investigation in science education. It poses a unique pedagogy that could be highly effective to help children studying science, to be knowledge builders not just knowledge reproducers. It signals that future-focussed learner capacities are connected with knowledge development and idea creation. If Knowledge Building is to be established as a future focus pedagogy, it highlights the need for teachers to understand both Nature of Science and the Knowledge Building principles. This model is about shifting beliefs and pedagogies. Science teachers require ongoing, sustained professional development to achieve this. There is an important role identified for future science education, it is to enable students to improve knowledge in a collaborative process. It is high time to engineer a shift of learning culture in our science classes in order to this.

Appendix

Scardamalia (2002) identifies twelve principles of Knowledge Building as follows:

1. Real ideas and authentic problems. In the classroom as a Knowledge building community, learners are concerned with understanding, based on their real problems and observations in the real world.
2. Community knowledge, collective responsibility. Students' contribution to improving their collective knowledge in the classroom is the primary purpose of the Knowledge building classroom.
3. Improvable ideas. Students' ideas are regarded as improvable objects.
4. Idea diversity. In the classroom, the diversity of ideas raised by students is necessary.
5. Rise above. Through a sustained improvement of ideas and understanding, students create higher level concepts.
6. Epistemic agency. Students themselves find their way in order to advance.
7. Democratizing knowledge. All individuals are invited to contribute to the knowledge advancement in the classroom.

8. Symmetric knowledge advancement. A goal for Knowledge building communities is to have individuals and organizations actively working to provide a reciprocal advance of their knowledge.
9. Pervasive Knowledge building. Students contribute to collective Knowledge building.
10. Constructive uses of authoritative sources. All members, including the teacher, sustain inquiry as a natural approach to support their understanding.
11. Knowledge building discourse. Students are engaged in discourse to share with each other, and to improve the knowledge advancement in the classroom.
12. Concurrent, embedded, and transformative assessment. Students take a global view of their understanding, then decide how to approach their assessments. They create and engage in assessments in a variety of ways.

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