Chapter 16
Developing Collective Decision-Making Through Future Learning Environments

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National reports such as *Rising Above the Gathering Storm* (National Academies 2006) and *Tough Choices or Tough Times: The Report of the New Commission on the Skills of the American Workforce* (National Center on Education and the Economy [NCEE] 2007) call for fundamental changes in the education system in the United States. In fact, the NCEE report categorically states that "the core problem is that our education and training systems were built for another era, an era in which most workers needed only a rudimentary education" (p. 8). The rapid evolution of technology in the twenty-first century is changing the needs for the workforce in general and more specifically in STEM fields; in turn, this changes the expectations for students entering this ever-changing workforce and the teachers who prepare them to do so. This is not only to develop the next generation of STEM workers but also to develop technological, or STEM, literacy for all. Hurd (1998) clearly indicates that current ways of teaching and learning "need to be reinvented to harmonize with changes in the practice of science/technology, an information age, and the quality of life" (p. 411).

Twenty-first-century knowledge and skills are garnering growing attention in the conversation about the transformation of schools for the current century. Proponents argue that within the context of core knowledge instruction, students must also learn the essential skills for success in today's world, such as critical thinking, problem solving, and communication. Central to the development of these skills is the ability to use twenty-first-century technology tools, such as information and communication technologies. Students of today are digital natives who live in a rapidly changing and developing technology and media-suffused environment with ready access to an abundance of information and collaborative and social-networking tools. Leveraging

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technology and new learning environments made possible through innovations in information and communication technology will be critical to develop the collaborative culture of problem solving needed for the schools of the future.

Visit almost any US school, you will still see the "700–900 square-foot classroom, superbly designed for a teacher to stand in front of a class of thirty students in neat rows, listening, taking notes, and doing worksheets" (Pearlman 2010, p.117). Even though today's classrooms have been equipped with many educational technology tools such as interactive whiteboards and computers, the vast majority of teachers are still using traditional teaching approaches (National Educational Association [NEA] 2008). This is surprising since one would intuitively expect that having easy access to the educational technology tools would promote learner-centered approaches to education. However, it has been documented that most teachers use computers to perform administrative tasks such as taking attendance (Becker 2001) or to replicate teacher-centered practices (NEA 2008). Unfortunately, very few teachers allow their students access to use educational technology tools to solve problems, analyze data, do research on the Internet, present information graphically, and participate in distance learning via Internet (US Department of Education 2003).

Billions of dollars have been spent to turn K-12 classrooms into twenty-first-century classrooms. In addition, recent education reforms call on teachers to use technology tools in meaningful ways that enhance student learning. The *National Science Education Standards* call for teachers to engage students in inquiry and to collect, analyze, and share scientific data (NRC 1996). Meaningful use of technology within inquiry-based instruction has been found to enhance student learning (Hug et al. 2005). For example, technology tools such as laboratory probeware allow for real-time data graphing that provides students with immediate feedback and develops students' data interpretation skills (Friedrichsen et al. 2001). Yet, in this era of financial investment and federal directives, most teachers are still not integrating technology into their classrooms. Successful use of technology is still challenging for most teachers since they experience numerous obstacles. These obstacles can be grouped in two basic categories: first-order barriers and second-order barriers (Brickner 1995). First-order barriers include external factors such as access to technology resources, technical support, and time to plan technology-rich lessons. Second-order barriers, on the other hand, include internal factors such as teachers' beliefs about teaching and technology and their openness to integrate technology.

It is often the case that today's schools are equipped with technology tools, and first-order barriers are considered to be less of a barrier to implementing technology-enhanced instruction. However, second-order barriers are a challenge as technology integration as recommended in the science education literature often requires teachers to restructure their belief systems about teaching and learning. Science teachers' personalities, beliefs about the effectiveness of technology on student learning, and pedagogical and content knowledge of the educational technology tools play critical roles in technology integration (Yerrick and Hoving 1999). For example, in a study of a school laptop initiative, Windshitl and Sahl (2002) found that teachers' beliefs directly mediated their use of laptops in their classrooms. For example, one teacher who viewed the laptop as a presentation tool rather than a learning tool ultimately did not encourage students' individual use of laptops in her classroom. Similarly, many schools have participated in interactive whiteboard initiatives to promote interactive whole-group instruction. However, the whiteboard is easily assimilated into science teachers' existing teaching styles and tends to reinforce teacher-centered presentation (Armstrong et al. 2005). Throughout the science education literature, technology integration initiatives utilizing interactive whiteboards, laptops, computer simulations, probeware, etc., make clear that teachers are the critical agents of change.

Windshitl and Sahl (2002) made particular note that laptops, as opposed to fixed desktops, afford the sharing and comparing of ideas among students. They noted that students would "reconfigure themselves into "learning cells" of two or more individuals. They would bring their laptops together to work jointly on a product or to share digital information resources (p. 201)." David, the second author of this chapter, is an advocate of technology-enhanced classroom practices, and he has extended this form of co-production and sharing of knowledge afforded by laptop computers to leverage the power of Web 2.0 technologies as a shared knowledge-building tool.

Social Issues

In addition to incorporating technology to enhance students' science learning, twenty-first-century skills, and personal development as citizens, socio-scientific issues (SSI) (Zeidler et al. 2005) should be incorporated in science programs. SSI are "usually controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues" (Zeidler and Nichols 2009, p. 49). Classroom discourses around SSI fosters students' argumentation, reasoning, and decision-making skills since students are required to use evidence-based reasoning. As emphasized earlier, these skills are critical for students to acquire in the twenty-first century. Thus, incorporating SSI in contemporary science classrooms is essential.

A Twenty-First-Century Classroom

When you walk into David's 9th grade biology classroom in a high-poverty, urban school with predominantly minority student populations, you will see students working in groups to complete a task, much like in any other science classroom where students solve tasks in groups. However, upon closer inspection you will see

Fig. 16.1 Student volunteer helping update table technology

the 3.5 ft square tables, at which they sit, are quite unusual. Students are looking through tempered glass tabletops at flat-panel computer displays, two computers per four-person table (see Figs. 16.1 and 16.2). This provides not only the traditional, clutter-free workspace on which to place microscopes, posters, soil samples, or plants, but it also provides a world of networked possibilities. Using recycled computer hardware (though new displays) and open source software and efficient network-booting design provided by Ubuntu, a popular version of Linux, David has created an affordable albeit unusual setup.

Knowledge Building

In spite of the growing emphasis within society and the workplace on teaming, collaboration, and participatory learning, schools still adhere to a model of learning which emphasizes individualized acquisition of knowledge (Lemke 2010). The development of both hardware and software as well as the explosion of computer interconnectivity has presented us with the capability of transforming a classroom from a collection of individuals working to learn science to a community of novice

Fig. 16.2 With the support of Web 2.0 capabilities and 3-D models, English Language Learners are able to explore the structure and function of DNA

scientists striving to create science knowledge in the public realm. David's classroom is designed around the theoretical perspective of knowledge building (Scardamalia and Bereiter 2003).

The knowledge creation metaphor subsumes both the participation and acquisition metaphors of learning, sidestepping the battlegrounds between the situated cognition and constructivist camps. Knowledge creation conceptualizes a community of practitioners (Brown et al. 1989) working together to create "knowledge objects." Although these knowledge objects are abstractions (e.g., ideas, questions, concepts), they have many of the properties of physical objects in that they can be constructed, worked upon, and improved. Knowledge creation is situated within the context of post-positivist epistemologies.

Knowledge building is a particular implementation of the knowledge creation paradigm, especially applicable to understanding the work of communities of scientists (Paavola et al. 2004). It is often described as a process of progressive problem solving and advancement beyond one's present limits of competence. Scardamalia and Bereiter (2006) propose six principles of knowledge building: community knowledge advancement, idea improvement, knowledge *of* in contrast to knowledge *about*, discourse rather than argumentation, use of authoritative information, and emergent understanding.

The principle of the community knowledge advancement theme supports the claim that creative knowledge work, which enhances the knowledge of the community rather than just an individual, should take place in classrooms. However, most current educational practices emphasize individual learning rather than advancing the knowledge of the classroom community. The second principle of knowledge building—idea improvement—suggests knowledge advancement is not simply progress toward existing truths; rather it is the improvement of ideas. Students are not expected to "prove" something accepted by authorities, but instead to use these authoritative knowledge sources to improve the knowledge of their community. The third principle builds on the argument that knowledge building is not about the development of factual knowledge (knowledge about) as is traditional focus of classroom instruction and assessment. Knowledge building is the process of developing conceptual understanding of scientific concepts and issues. Another critical principle of the knowledge-building approach is that it favors classroom discourse rather than argumentation. The goal of the knowledge discourse is idea improvement, whereas argumentation places emphasis on "evidence and persuasion" (Scardamalia and Bereiter 2006, p. 102). Furthermore, knowledge building encourages students to become skeptical about the authoritative information which is the fifth principle. Rather than simply accepting information from the Internet or books, students are encouraged to judge the quality of the information.

In his book, Education and Mind in the Knowledge Age, Bereiter makes a distinction between learning and knowledge building (Bereiter 2002):

> [In knowledge building] learning does occur but it is not the main focus of these domains of activity. The primary goal of members of an innovative expert community is not merely to learn something but to solve problems, originate new thoughts and advance communal knowledge.

In other words, people in this community develop, create, understand, and criticize various conceptual artifacts; they don't just (individually) learn something. Advances in technology provide a critical affordance in structuring a classroom for these kinds of knowledge-building interactions. Instant and seamless access to computers, as in David's room, multiplies the potential.

Technology and Knowledge Building

Technology is an invaluable tool for teachers to form knowledge-building communities in the classroom. Knowledge building in a classroom has an interesting relationship with computer technology: without particular computer applications, knowledge building is unlikely on a long-term basis (Scardamalia and Bereiter 2006). Two well-known web-based knowledge-building solutions for classrooms include the proprietary Knowledge Forum and the open source Future Learning Environment (currently version 4 FLE4). David used FLE3 for three years and is now in his second year of using FLE4. Versions of FLE up through version 3 contain a suite of tools for communities of students to collectively and effectively build knowledge. FLE4 is no longer a suite of tools; the developers extracted the critical and most unique component of the software and transferred it to the most popular Internet blogging software, "WordPress." In doing so, they are bringing the potential of this discourse software "to the masses." Both versions of Future Learning Environment were designed and built by a group of education researchers at the Media Lab, University of Art and Design in Helsinki, Finland (for more information, http://en.wikipedia.org/wiki/Fle3).

FLE4 is used by David and other science teachers to develop communities of novice scientists in their classrooms. Through using FLE4, classes strive to answer core scientific questions by searching for and collecting information, developing working theories, and constantly improving these working theories, all toward the goal of answering the big questions developed by the teacher and their community. A critical aspect of FLE4 and knowledge building is *classroom discourse*. The knowledge-building discussions provide meaningful context for student inquiries and also effective strategies for teachers to assess student learning.

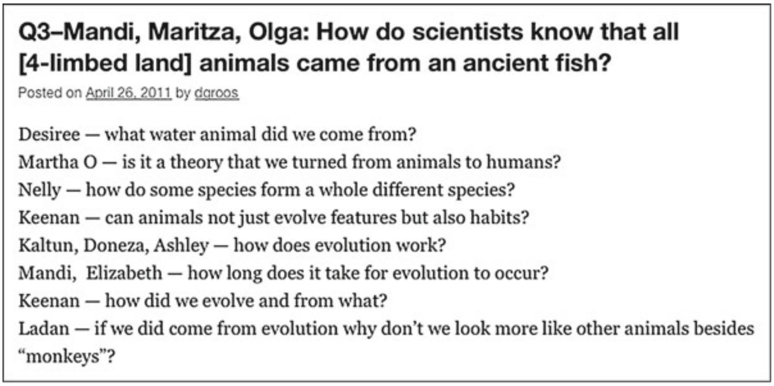
FLE4 in Action: Initiating Knowledge Building

The topic of Evolution is an example of a recent unit implemented in David's 9th grade biology classes. Students had recently finished a unit on Mendelian genetics, as well as an introduction to molecular genetics, so they were primed for this challenging topic. Following a pre-assessment of students' current understandings of evolution, David immediately began to intellectually engage his students in the concepts and contexts underpinning this theory. Students examined a newspaper article about new research on the original domestication of dogs, an online reading of the history of corn, and an online simulation of breeding ("biomorphs"). This activity provided a fun and interactive context in which the teacher could assess students understanding of breeding (artificial selection) while teaching important concepts.

The next stage of the evolution unit involved setting up the knowledge-building discourse. Using the online PBS video, "What Darwin Never Knew," David encouraged students to generate questions that were of interest to them as they watched the video. Each class generated between 40 and 80 questions which they organized into five to seven thematic groups. To set up a class knowledge-building discourse, David selected a single student's question from each group and designated it as that group's "big question," representing all questions in that group. These final big questions become the centers of inquiry and knowledge building for each class.

FLE4: Scaffolding Students' Responses

FLE4 looks deceptively simple, starting out as a very short blog post. For example, in Fig. 16.3, the title of the post shows one of the big questions from one class, while the text under the "big question" lists the other student questions within this thematic grouping.



Q3–Mandi, Maritza, Olga: How do scientists know that all [4-limbed land] animals came from an ancient fish?

Posted on April 26, 2011 by dgroos

Desiree — what water animal did we come from?
Martha O — is it a theory that we turned from animals to humans?
Nelly — how do some species form a whole different species?
Keenan — can animals not just evolve features but also habits?
Kaltun, Doneza, Ashley — how does evolution work?
Mandi, Elizabeth — how long does it take for evolution to occur?
Keenan — how did we evolve and from what?
Ladan — if we did come from evolution why don't we look more like other animals besides "monkeys"?

Fig. 16.3 Initiating knowledge building—introducing a "Big Question"

The stage is now set for students to enter into the discussion. During the first online participation, students declare their initial positions by posting comments to the big questions. While threaded commenting systems are common fare on the Internet, FLE4 introduces a clever twist and thereby "scaffolds" a classroom of novice scientists to engage in knowledge building at a level beyond what they could do without it. FLE4 accomplishes this by requiring students to select the intent of their post before creating it. Students must choose between five predefined kinds of posts or "knowledge types." These knowledge types correspond to five different kinds of contributions that expert scientists make as they engage in knowledge building: Problem-Question, My Explanation, Scientific Explanations, Observations of the Process, and Putting it all Together.

For the initial knowledge-building session, David instructs students to use either the "My Explanation" or the "Problem-Question" knowledge types. Figure 16.4 shows another big question (from a 9th grade biology class), while Fig. 16.5 shows two student posts that followed. On the computer screen, My Explanations are a dusty green and Problem-Question posts are yellow, further scaffolding student communications.

The initial dialog, as illustrated in Fig. 16.5, is critical in setting the stage for more advanced learning and the development of scientific explanations. This first step allows students to put forward their ideas, opinions, and explanations; in effect it initiates a personal relationship (in the public realm) between the big question and the student and between the students themselves. These first interactions on FLE4 allow David to view the range of understandings and beliefs on the topic. It also allows him to develop activities for the class that are responsive to student ideas.

The following screen shot is from further down the same thread and shows that Eddy also challenges those who espouse a scientific position (Fig. 16.6).

The teacher's role in facilitating this discussion is complex, just as is teaching in general. The knowledge-building discussion provides a meaningful context for including readings, inquiry activities, direct instruction, simulations, concept mapping, and other instructional activities. While planning is very important in a

Fig. 16.4 Another big question created by the 9th grade class

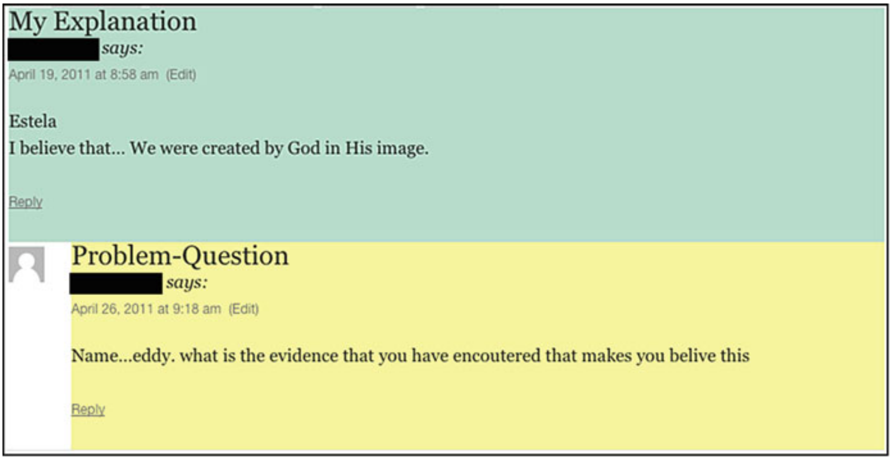


Fig. 16.5 Initiating a knowledge-building discussion

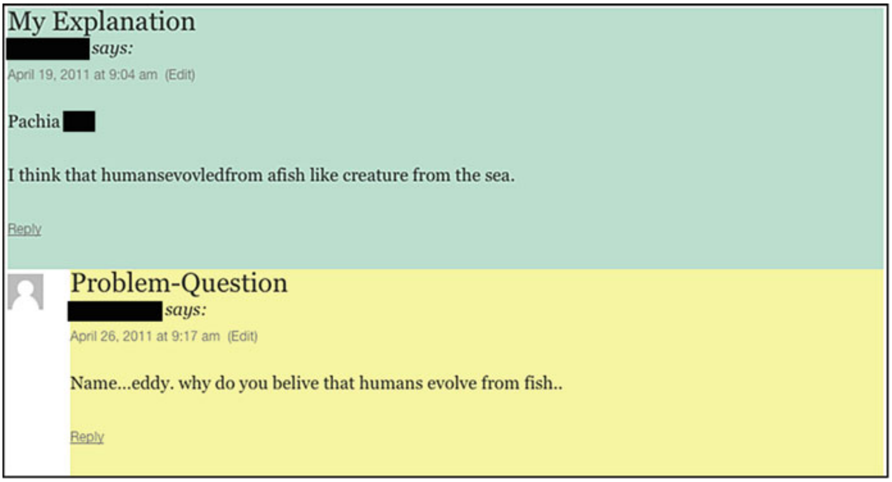


Fig. 16.6 Continuation of a knowledge-building thread

knowledge-building classroom, spontaneity which builds on current student discourse increases student buy-in and motivation in the process. For example, in seeing many students demanding of evidence, David was able to refer to those posts when introducing fossil evidence of evolution.

Advantages of FLE4

A traditional class discussion could of course also help students to build knowledge and is still an important instructional strategy. However, the FLE4 knowledge-building tool provides important benefits. Embedding images and hyperlinks to informative web pages and simulations into the forum allows for many ways and levels of participation, in other words, "differentiation." Also, in general, a more profound depth of thinking occurs when students write as opposed to simply talk. Perhaps most importantly, written discussions provide the community of novice scientists with a searchable archive of student contributions, serving many possible purposes.

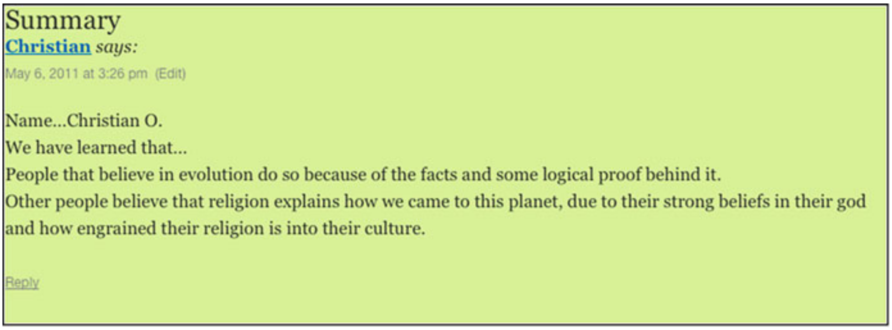
Students are accustomed to constant interaction with peer "friends," multitasking. Upon entering a science classroom, even in collaborative discussions, there still is a preponderance of one person talking and everyone else listening. And it is well known that the teacher occupies the lion's share of discussion space. By providing students with access to a scaffolded discussion tool in the classroom, all students can constantly engage in an active capacity in the community. This active engagement is ideal for ELL students. Students are able to read and reread comments from peers as well as science resource materials, as much as necessary to understand the information. Additionally, they have full opportunity to produce language (in writing), giving them opportunity to edit and reedit their communications. FLE4 provides ELL student the opportunity to practice more difficult and educationally significant academic language.

In a classroom where dialog is only oral, comments come and go and complex, extended conversations are rare. Some conversations require time and mature not over minutes but days. These extended conversations are difficult to maintain in an exclusively oral discussion environment. For example, the Summary post shown in Fig. 16.7 sums up 12 previous posts made over a 10-day time period. The responding Problem-Question post shown in Fig. 16.8 was made just four min after the Summary post and eloquently initiates a deeper round of inquiry.

Assessing Student Learning

Assessing discourses allows teachers to evaluate students' critical thinking skills and abilities in ways that cannot be assessed through standard summative assessments. As noted earlier, student discourse is an essential component of knowledge building and non-coincidentally a central goal for proponents of twenty-first-century skills.

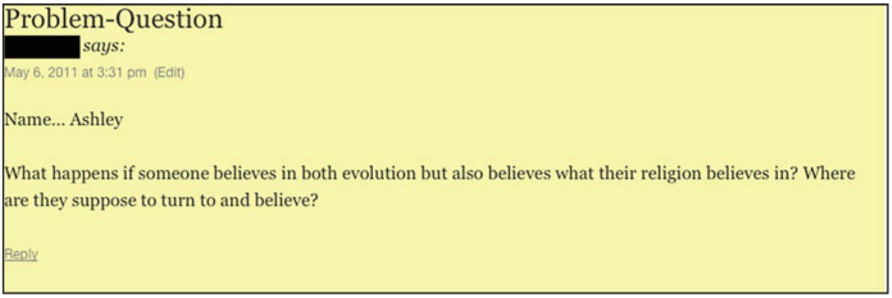
Before examining FLE4 as an assessment tool, it is important to indicate inappropriate assessment approaches. While it would be easy to measure student


Summary
Christian says:
May 6, 2011 at 3:26 pm (Edit)

Name...Christian O.
We have learned that...
People that believe in evolution do so because of the facts and some logical proof behind it.
Other people believe that religion explains how we came to this planet, due to their strong beliefs in their god and how engrained their religion is into their culture.

Reply

Fig. 16.7 A Summary post summarizing the sources of student beliefs about evolution


Problem-Question
[redacted] says:
May 6, 2011 at 3:31 pm (Edit)

Name... Ashley

What happens if someone believes in both evolution but also believes what their religion believes in? Where are they suppose to turn to and believe?

Reply

Fig. 16.8 A Problem-Question post launches an ever-deepening inquiry

participation by number of posts as is often done in some systems, this is discouraged. Ostensibly this measures productivity and participation; however, as experienced teachers know, “good students” learn to play the system and would out of habit focus on their post-count at the expense of quality and significance or authenticity of the posts. Similarly, one should be cautious of assessing the correctness of usages of science concepts in a post. While the scientific accuracy of a post can and should inform a teacher’s practice, what counts in knowledge building is how someone’s idea, whether correct or not, initiates or advances a scientifically significant dialog. Sometimes errors, or in this case scientifically incorrect posts, initiate more meaningful and significant knowledge-improvement dialogs. By placing a premium on correct use of concepts in a dialog, students’ sincere participation would not be recognized and instead be discouraged through this process.

Uses of FLE4 in Assessment

FLE4 plays an important role in David’s assessment system. The unit of assessment is both the individual and the community as a whole. When assessing the whole community, David analyzes the relationship between individuals and the class, aiming at better understanding of the hard-to-measure synergy a teacher aims for in his/her communities. For individual assessment, David focuses on what American Association for the Advancement of Science (AAAS) refers to as “habits of mind” including Values and Attitudes, Communication Skills, and Critical-Response Skills (AAAS 2009).

To better understand how FLE4 richly informs a teacher of students’ development of Critical-Response skills, we examine student dialog in light of the specific learning goals from AAAS (2009). For example, students should ask and respond to the question “How do you know…” as shown by Eddy in Figs. 16.5 and 16.6. Students are expected to be able to “Buttress their statements with facts found in books, articles, and databases, and identify the sources used and expect others to do the same” and “Seek reasons for believing something rather than just claiming “Everybody knows that…” or “I just know” and discount such claims when made by others.” Eddy’s posts in Figs. 16.5 and 16.6 are pushing for students to provide evidence and rationale for their statements in this early stage of the knowledge-building process.

As the discussion proceeded and students attempted to provide scientific explanations for their positions, it became clear that they were confused and were arguing over whether scientists said we had come from fish or from monkeys. Students also struggled to explain how new species were generated. For example, in Fig. 16.9, a student is responding to the big question “How did the animals in the Galapagos become different from the animals in the other parts of the world?” with a scientific explanation that reveals an alternative conception.

FLE4 thus provides a powerful formative assessment tool that allowed David to see that his students were unable to meet his learning goals related to critical-response skills and evolution content. David was able to provide a just-in-time lesson to assist students with their questions. The second and third posts in Fig. 16.9 follow David’s mini-lesson. The third post shows improved understanding as it integrates the information that the Galapagos Islands is not just one island but a collection of 13 islands with different characteristics. This knowledge artifact is an important resource and a source of pride for the community. There is something special in that it was created by a student in the class, not a video, teacher, or book. As others recognize the significance of her contribution, her status in the knowledge-building environment will rise. We note that all three of these posts failed to include a reference to their sources; this illustrates the students’ lack of sophistication with this knowledge type.

FLE4 provides students with an opportunity to engage in sincere dialogs, as initiated in Fig. 16.6 where Pachia states her belief that we came from a fish-like creature but at that time is unable to provide evidence. In the continuation of this thread (Fig. 16.10), Pachia responds and Valeria echoes her sentiment expressing doubt in the authority of scientists. However, eight minutes later, Valeria qualifies her statement with the acknowledgement that they do know about adaptation changing over time in a population because *they* did an activity with “sporks and spoons.” Comments like this provide teachers with knowledge about students’ beliefs on the nature of knowledge, as well as the effectiveness of their instructional sequences. Finally, we note here that students are still learning how to use the knowledge types

Fig. 16.9 Scientific knowledge type used in dialog

and that Valeria's final post is an "Observation of Process" not a "Scientific Explanation," although it is interesting following the progression of this thread that students assign themselves the voice of a scientist in selecting this knowledge type.

Final Remarks on FLE4

Online discussions are known to be an effective tool for students to develop and experiment with their classroom identity or persona. This experimentation is especially active toward the start of the school year and generally includes instances of bullying and limit testing. These aspects of a discussion are an important indicator of the health of a classroom and an opportunity to improve it. These challenges are publically made and must be addressed. Since only the teacher can delete a comment in the FLE4 discussion, students in David's class who make antisocial comments quickly learn that this kind of interaction can't be hidden and won't be tolerated.

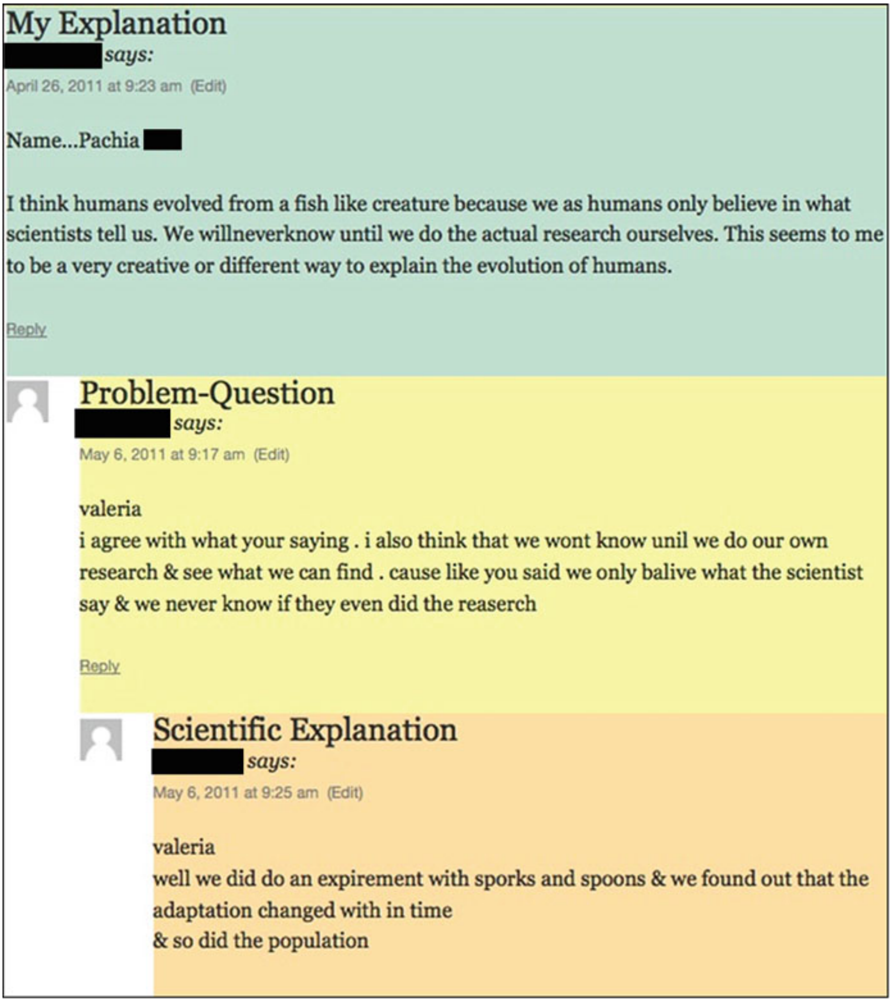


Fig. 16.10 Continuation of thread shown in Fig. 16.6. Though error in knowledge type, Valeria shows learning

Although David sets limits through FLE4, he constantly uses it to highlight pro-social comments, encouraging the growth of a positive classroom environment.

In many ways nonetheless, this experimentation with identities continues throughout the year. For example, it is interesting to watch students "try on" a "scientist's voice" using the specific vocabulary and formal sentence structure of science, something many students might never be bold enough to do if the only classroom medium for discussion were oral. Also, these students might never have been willing to try this foreign voice, this voice of a scientist, if their familiar voice had not been fully accepted in the community of scientists. FLE4 provides a medium though which this voice can be heard and developed.

Conclusion

In the twenty-first century, we have witnessed the rapid development of educational technology tools and reform efforts to transform classrooms to technology-enhanced learning environments. What have we learned from the educational reforms on technology integration? Successful technology integration is not a quick and easy process. While there are some "exemplary teachers," such as David, who can use technology effectively, it is well known that "individual teachers cannot bring about a sustainable school-wide change… and individual schools cannot bring about system-wide change" (Law et al. 2008, p. 25). Change cannot occur without holistic, systematic reform. A systematic reform deals with various issues at different levels (e.g., school level and national level) and involves a range of problems simultaneously. When systematic reform concerns the use of technology, it is critical to consider conditions at the teacher level (such as knowledge, confidence, and level of access), school level (such as technology infrastructure), state level (such as funding), and national level (such as policy makers).

In most current reforms, technology is presented as a simple solution to improve education. "Technology is not a panacea for educational reform, but it can be a significant catalyst for change" (Sandholtz et al. 1997, p. 186). Technology is a powerful tool to support student-centered educational approaches that are responsive to calls, such as twenty-first-century learning, to develop critical thinking. Particularly, as applied in David's classroom, technology has great potential to apply knowledge-building pedagogy which "involves students not only developing knowledge-building competencies, but also coming to see themselves and their work as part of the civilization-wide effort to advance knowledge frontiers" (Scardamalia and Bereiter 2006, pp. 97–98).

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