Chapter 1
Interactions Affording Distance Science Education

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Introduction

Teaching and learning of science concepts and practice has traditionally been an interactive process. That interaction most often takes place in classrooms and includes the passive consumption of lectures, intermingled with hands-on work in laboratories or field locations. These activities are interspersed with student interaction with textbooks, computers and the completion of learning activities such as problem sets. Distance and distributed education affords new possibilities (especially related to increasing access) at the same time as it reduces capacity for traditional science instructional models and activities. In this chapter, I overview the value of interaction, briefly discuss the literature on definitions and types and conclude with implications and suggestions for creating interaction designs and mixes that together create exciting and engaging ways for science students who are distributed across time, space, and cultures.

Interaction has become synonymous with engagement, activity, and fun as illustrated by the deluge of advertising for everything from interactive toys to interactive clothing, books, music, and concerts. The adjective 'interactive' implies a degree of involvement. (National Institute for Education, 1984), mindfulness (Langer, 1997), and flow (Csikszentmihalyi, 1990). Educational researchers have linked interaction with higher levels of persistence and perceptions of better learning (Picciano, 2002).

Though often associated with widespread and multifarious use, the term interaction is plagued with conceptual misunderstanding. Educators' wide use of the term implies a need for sharper definition and meaningful qualification as to the effective use of interaction in their teaching and learning programs. Advertisements promoting "interactive toasters" make us realize that educators need to clarify and be more specific about the definition, nature, quality, and expectations of interaction in the educational process.

Defining interaction

The education literature contains a number of definitions of interaction which I have summarized in previous work (Anderson, 2003b). At debate in discussion about definitions is the exclusiveness of the term such that it is reserved for exchanges and dialogue among people as opposed to people engaging with machines or learning objects. Perhaps the most well-known definition is that provided by Wagner (1994), who defined interaction as "reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another" (p. 8). Obviously, this definition includes engagement with non-humans and implies the capacity for both actors (or objects) to influence each other, thereby implying two-way control — a subject that has special interest as I discuss later in the interesting use of virtual labs.

Michael Hannafin (1989) itemized the functions that interaction purports to support in mediated educational contexts. These are:

1. **Pacing:** Interactive pacing of an educational experience operates

from both a social perspective, as in keeping an educational group together, and an individual perspective, as in prescribing the speed with which content is presented and acted upon.

2. Elaboration: Cognitive science informs us that interaction develops and reinforces links between new content and existing mental schema, allowing learners to build more complex, memorable, and retrievable connections between existing and new information and skills (Eklund, 1995).

3. Confirmation: This most behavioural function of interaction serves both to reinforce and shape the acquisition of new skills. Conformational interaction traditionally takes place between student and teacher, but is also provided generally by feedback from the environment provided through experience, and while working through content presented in computer-assisted tutorials or as "answers in the back of the book" and from peers in collaborative and problem-based learning.

4. Navigation: This function prescribes and guides the way in which learners interact with each other and content. Its function becomes more important as we begin to appreciate and utilize the hundreds of thousands of learning objects and experiences provided on the Net. Interaction feedback provides data necessary to channel and selectively guide learners through this maze of learning possibilities to those that are individually appropriate, accessible, and meaningful (Koper, 2005).

5. Inquiry: Hannafin's conception of inquiry in 1989 focused on inquiry to the computer system that was displaying content and monitoring student response. The interconnected and wildly more accessible context for inquiry now provided by the Net opens the door to much greater quantity and quality of inquiry. The interactive affordance for learners to follow individual interests and paths makes inquiry both a motivating and personalizing (though potentially distracting) function of learning.

To these I add the 'study pleasure and motivation' that Holmberg (1989, p. 43) describes as developing from interaction and relationship between teachers and students.

Thus, interaction fulfills many critical functions in the educational process. However, it is also apparent that there are many types of interaction and many actors (both human and inanimate) involved. As a result of this complexity a number of distance education theorists have broken the broad concept of interaction into component types, based largely on the roles of the human and inanimate actors involved.

Types of interaction

Moore (1989) differentiated three types of interaction which, since they focus on student behaviour, are the most important for educational applications. These are student-teacher, student-content, and student-student interactions.

Student-teacher interaction

Student-teacher interaction has been hailed by traditional educators and many students as the pinnacle and highest valued of interactive forms. This form of interaction is the basis upon which apprenticeship models of education and training are grounded (Collins, Brown, & Newman, 1989). The American President James Garfield was reported to have defined the ideal university as "Mark Hopkins [then President of Williams College] at one end of a log and a student on the other." Since then the 'log' has expanded into cyberspace and the conversation has extended talking options into multiple audio, text, and video formats. Yet there remains a sense that personal identification and other aspects of 'teacher presence' (Brady & Bedient, 2003) are important, if not critical, components of the educational process. The problem with teacher-student interaction is that there is only a limited amount of 'room on the log.' Further, the teacher often is not sitting on her 'end of the log' when their intervention is most advantageous for the learner, and finally, the student may find herself thousands of miles away from the log when instruction and support are needed. Simply put, student-teacher interaction is not scalable. Teacher-student interaction has been stretched — or perhaps stressed is a better term — to include 500-seat lecture theatres, but at a certain size interaction that does occur is mostly vicarious and certainly fails to produce the effects noted by Hannifin earlier.

Student-teacher interaction in distance education has traditionally been limited to occasional and usually student-initiated conversation mediated by the post, the telephone, or more commonly today, through Net-based interaction. The continuing increase in sophistication and complexity of computer-assisted instruction and the use of teacher agents (Yu, Brown & Ellen Billett, 2007; Feng, Shaw, Kim & Hovy, 2006; Moreno & Mayer, 2004) allow some of the student-teacher interaction to be replaced by student-content interaction, but the goal of building machine systems that can completely replace student-teacher interaction remains elusive and perhaps undesirable.

Student-teacher interaction is, however, valued by both students and teachers and has been found to be associated with positive perceptions of learning (Wu & Hiltz, 2004). Thus, provision is made for such interaction in almost all forms of formal education. Its costs, though, dictate that it must be used judicially. Interactions focused on affective concerns such as motivation, personal issues, and modelling represent perhaps the most effective use of teacher-learner interaction. Perhaps the most commonplace and effective way to "increase access to the log" has been through converting student-teacher interaction to student-content interaction, to which we next turn.

Student-content interaction

Student-content interaction first evolved through the transcription into text of oral stories and teachings. Historically, biblical scrolls and other sacred writings illustrate this type of interaction. Furthermore, student-content interaction still defines much learning activity today as students routinely part with hundreds of dollars annually in the university bookstore. In recent years, student-content interaction tools have become much more sophisticated and accessible. Learning games, simulations, immersive worlds, virtual labs, quizzes, podcasts and videocasts, blogs, and wikis are just a few of the new networked tools that allow students to interact with content in multiple formats enhanced by color, video, audio, animation, and the processing capabilities of powerful computers. The Net further makes this content available "anytime, anywhere."

The easiest, least expensive way to gain economy of scale is to record student-teacher interaction and convert it to student-content interaction. As noted, this model has been used for millennia to allow vicarious student-teacher interaction through texts with seers long since passed away. More recently, audio and video clips (podcasts and videocasts) have been created to record, store, and deliver this type of interaction. A hybrid form of student-teacher interaction has been developed whereby teachers create presentations on the Net (often referred to as blog postings) and students may, though typically they do not, reply or ask additional questions of these teachers. A good example of this is the Science Blog http://scienceblogs.com/ site, at which over 60 professional scientists were selected "based on their originality, insight, talent, and dedication" to post science-related reflections that can be used and commented upon by students.

Formerly, student-content interaction was a consumptive activity in which students interacted with content created by teachers and other experts. More recently the practical and pedagogical value of learners creating and sharing their own content, as celebrated in so-called Web 2.0 applications (O'Reilly, 2005), has captured public and educational attention. The construction, by all levels of students, teachers, experts, and lay people, of digital resources such as Wikipedia or the more focused creation by sets of discipline experts such as Science Environment for Ecological Knowledge (SEEK) http://seek.ecoinformatcs.org/ demonstrate the utility and cost-effectiveness of user-generated content. Pedagogically, the value of content creation instead of or in addition to content consumption has been shown to deepen commitment and quality in learning outcomes (Anderson, 2007; Collis & Moonen, 2001).

Finally, we turn to the most cost-effective and arguably the most pedagogically effective form of learning interaction — that which occurs between student and student.

Student-student interaction

Student-student interaction is associated with academic accomplishment (Johnson, Johnson & Smith, 1998), the development of social capital (West-Burnham & Otero, 2006), and enjoyment in the learning process (Johnson, 1981). However, most of the evidence for these claims comes from face-to-face interaction that begins in the campus classroom, but often is continued elsewhere. For example, in a meta-analysis of 383 studies over 20 years Springer, Stanne and Donovan (1999) found that "students who learn in small groups generally demonstrate greater academic achievement, express more favorable attitudes toward learning and persist through science, mathematics, engineering and technology courses to a greater extent than their more traditionally taught counterparts" (p. 21).

The support for student-student interaction reveals a great and as yet unresolved tension among distance educators. For many seminal distance education theorists, including Holmberg (1989), Peters (1988), and Keegan (1990), distance education was an individual activity defined by rich and highly developed student-content interaction (professionally designed and delivered in high-quality learning packages), supplemented by irregular one-on-one student-teacher interactions. Champions of this model argued that individualized learning is an inherently superior form of higher education, because of its ability to overcome time, place, and pacing constraints, its economic scalability, the support for individualized (one-on-one) interaction between a student and a teacher and the concomitant development of a learner's capacity to be self-directed and self-motivated. The flexibility offered by this model is associated with the absence of scheduling, commuting, meetings, and other constraints and is a major reason why students choose to take courses at a distance (Poellhuber, 2005).

However, many authors have noted the lack of social interaction and the higher attrition rates associated with self-paced study and have linked this to a sense of student isolation (Morgan & McKenzie, 2003; Anderson, Annand, & Wark, 2005). One of the solutions envisioned to the lack of social interaction is to stimulate both synchronous and aysnchronous student-student interactions, thus creating a socialized form of distance education that Garrison and Shale (1990) defined as "education at a distance" rather than distance education. This distinction underscores the availability of rich (though mediated) student-student and student-teacher interaction that is celebrated (though, as noted, not always achieved) in campus-based forms of education.

To afford opportunity for student-student interaction, the majority of networked distance education or e-learning consists of groups of students, forged into cohorts, who progress through a series of learning activities while hopefully forming a supportive learning community. The Community of Inquiry (COI) model is the most widely cited theortical model for this type of paced and cohort-supported model of distance learning. This model and subsequent techniques to validate it were developed by myself and colleagues at the Univeristy of Alberta (Garrison, Anderson & Archer, 2001). The model describes the necessity of supporting three types of 'presence' if quality distance learning is to occur. These include teaching presence (largely, though not exclusively supplied through student-teacher interaction), cognitive presence (activities designed to instigate and support critical thinking skills), and social presence (the capcity to present oneself as a 'real person' and to engage in effective, integrative, and cohesive activities). This model brings the notions of social constructivism (Vygotsky, 1978; Lave, 1988; Jonassen & Carr, 2000) to distance education. Extensive applications of and studies using the COI model have shown that each of these three presences can be created at a distance. Further, the student-student interaction in paced and cohort-supported models of distance education can lead to the development of social support networks and social capital (West-Burnham & Otero, 2006; Daniel, Schwier & McCalla, 2003). In a 2004 meta-anlysis of distance programming, Bernard et al. (2004) found that distance education models that supported student-student interactions through paced and interactive activities had higher persistence rates than those based on individual study.

Unfortunately, group-paced models of distance education are associated with major restrictions of learner freedom (Paulsen, 1993), the two most critical being the time when learning can commence (enrolment dates) and the pacing or the length of time used to complete the course or program of studies. It is sometimes impossible for non-traditonal students and those with major work, family, or community obligations to synchronize their time with that of a cohort of students and the teacher. Thus, until recently they were forced to engage in educational models that required and supported only individualized learning with no student-student interaction. We are, however, seeing the dawn of a new paradigm of distance edcuation in which self-paced learners use "social software" to work co-operatively, for short time periods, in 'study buddy' or study groups, thereby gaining the benefits associated with rich student-student interaction. The key to this next generation of distance education is sophisticated social software that allows learners to find each other, schedule activities, and support the co-operative construction of learning artefacts (Anderson, 2006).

Many of the techniques developed for classroom groups have been successfully adapted to learning groups operating at a distance. However, discussions about the means, if any, to facilitate group collaboration in learner-paced education models is notably absent from the literature. While technologies exist to facilitate synchronous and asynchronous forms of group interaction, facilitating this collaboration among groups of learners — in a self-paced setting — is still problematic. This distinct divide between distance education theorists in regard to the value and means to support self-paced distance edcuation models appears to be essentially unresolved at present. Optimizing the flexibility of self-paced learning and the advantages of collaboration and social support remains an open and exciting challenge.

Equivalency of interaction

In 2003, I published an article (Anderson, 2003a) overviewing these three modes of interaction and claimed (somewhat tongue-in-cheek) that the value of learning is roughly equivalent among the three types of student interaction and that a high level of one form of interaction allows the other two to be reduced or even eliminated, without loss in learning effectiveness. Thus, high levels of student-teacher interaction (discussion at either end of the log!) mean that student-student and student-content interaction can be drastically reduced. Most of the implications of this "equivalency theorem" were confirmed by Bernard et al. (In Press), who found that increasing the quantity and quality of any of the three student-focused forms of interaction did increase student performance. Interestingly, increasing student-teacher interaction, despite being the most costly intervention, had the least effect on student performance as compared to student-content and student-student interaction. This equivalency theorem challenges educators to think more clearly about the advantages and limitations imposed by each form of interaction and to 'get the mix right.'

Interaction in science-based distance education

Since the development of 'modern' forms of distance education in the 1960s, distance science educators have struggled with the means to provide experience and training that has traditionally taken place in the science laboratory. Kirschner and Meester (1988) claim that "a university study in the natural sciences, devoid of a practical component such as laboratory work is virtually unthinkable" (p. 81). Despite this universal endorsement, the efficacy and pedagogy of lab-based education has been criticized for a number of shortcomings, including triviality, repetitive, rote 'recipe' following, inadequate supervision, and a poor return on student time invested (Kirschner & Meester, 1988). The logistical problems associated with developing and delivering lab experiences at a distance further exacerbate these challenges. However, distance educators are nothing if not inventive and persistent, and they have developed a variety of techniques and designs (see chapters in this volume) to address these problems while maintaining high levels of accessibility — the raison d'être for distance education programming. Most predominantly, distance educators have used occasional face-to-face labs sessions offered in centralized locations, the development of home- or industry-based science lab kits, and more recently, use of immersive environments and virtual and remote labs.

Rather than overview challenges, accomplishments, and examples of distance science instruction contained in later chapters, I will note that the predominant learning model, as in most traditional distance education programming, is based on high-quality learner-content interaction. As in other education, entertainment and commercial applications, the development of media, and especially Web-based tools, now support very sophisticated forms of learner-content interaction. These applications still retain high levels of accessibility through the ubiquitous Net, providing access to learners who are globally distributed.

Student-student interaction in distance science programming has often been focused on irregular face-to-face gatherings at lab sessions. Where this is logistically impossible, cohort-based models typically create spaces where students can engage in conversation, provide informal assistance to each other, and occasionally work on co-operative or collaborative projects. The nearly ubiquitous connectivity provided through text tools such as Instant Messenger and audio and video through Skype and workspace sharing via web conferencing systems such as Elluminate creates rich yet low-cost opportunities for student-student interaction in distance education. However, as always, the use of these tools must be embedded within effective learning activities that are perceived as valued by students if they are to be used at all and to result in meaningful learning outcomes. The familiar instructional designs used by distance educators in self-paced programming have often either been formally or informally designed with a sense that students are working alone. This assumption is no longer tenable and challenges instructional designers to create designs that are not only vulnerable to collaborative cheating, but that use collaborative possibility to enhance educational programming. There is a very substantial body of literature detailing the social and cognitive benefits that are afforded by well-designed collaborative and co-operative programming in both face-to-face (Johnson, Johnson & Smith, 1998) and computer-mediated distance education contexts (Koschmann, 1996). Our challenge is to integrate these techniques into programming that has a celebrated tradition of individualized learning.

The very recent development of accessible immersive environments such as SecondLife or Active Worlds heightens the sense of presence, stimulation, engagement, and enjoyment (see, for example, Harvard University's River City Project http://muve.gse.harvard.edu/rivercityproject/). Besides the capacity to support unique new forms of student-content interaction, the social nature of these environments affords development of informal and formal co-operative and collaborative science learning activities. An immersion-based introduction to learning science in the currently most popular Web-based immersive environment, SecondLife, produced by the University of Michigan at http://video.google.com/videoplay?docid=4594846425520495909, provides a fascinating overview of student-content interaction in Net-based immersive environments. These environments promise to augment student-content interaction with engaging new contexts and techniques not accessible in any environment, including the traditional science laboratory. And of course, immersive environments provide rich forms of student-student interaction that is enhanced by the social presence afforded by avatar body language, gestures, and sounds (McKerlich & Anderson, 2007).

The next frontier in distance education programming is providing rich student-student interaction in unpaced, continuous enrolment programs. At Athabasca University we are developing tools and a research program that uses the new genre of social software to allow self-paced students to meet each other and work co-operatively on short-term projects in addition to forming optional study buddy and study group relationships with other students. Social software suites such as Elgg, Ming, and FaceBook provide tools that allow students in related courses to synchronize their activities for brief periods of time and to safely introduce themselves to others through selective release of personal information.

Conclusion

Interaction stands at the centre of the educational experience. As distance educators we are both allowed and compelled to use mediated forms of this interaction. In some cases the media is costly and gets in the way of learning. In other cases it can result in hyper-learning that easily surpasses non-mediated forms of learning. In all contexts we seek a balance of student-teacher, student-student, and student-content interaction that is cost- and learning-effective. The laboratory requirement in science-based education contexts presents unique challenges to distance educators, but the emerging Net-based information and communication tools afford many new ways in which each of these forms of interaction can be enhanced. The chapters in this book reveal ways in which innovative distance science education are meeting this challenge. Much remains to be done, especially development of robust research programs to generate and share knowledge generated from these innovations. However, the future of distributed science education seems filled with the promise of exciting new ways for learners and teachers to explore and develop their understanding of our expanding universe.

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