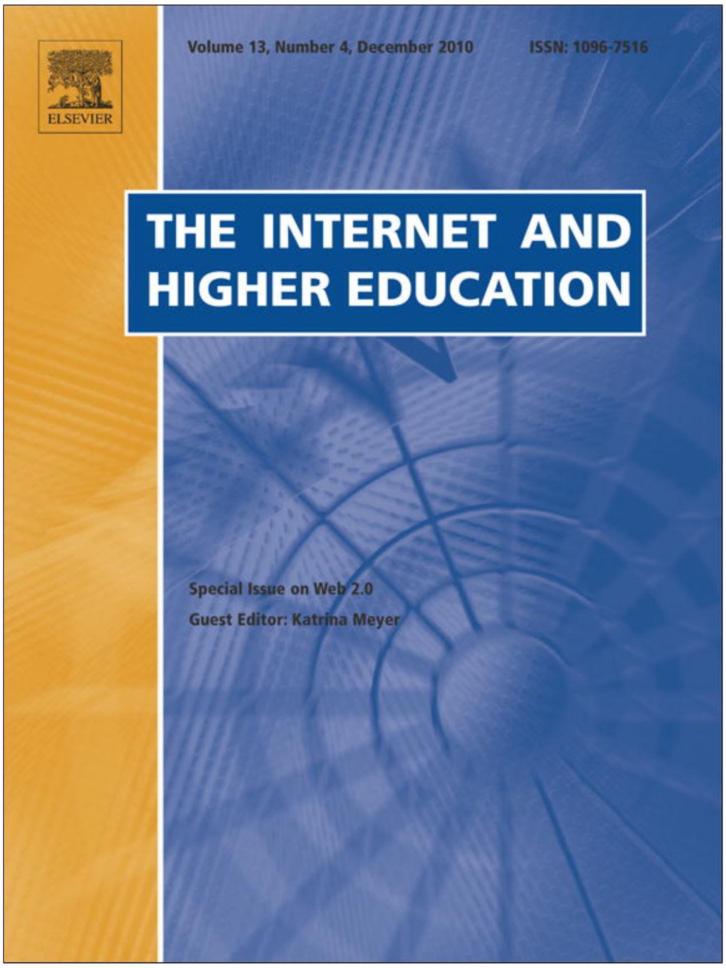
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Project-based learning and student knowledge construction during asynchronous online discussion

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ABSTRACT

Project-based learning engages students in problem solving through artefact design. However, previous studies of online project-based learning have focused primarily on the dynamics of online collaboration; students' knowledge construction throughout this process has not been examined thoroughly. This case study analyzed the relationship between students' levels of knowledge construction during asynchronous online discussions with respect to engagement in project-based learning. Graduate students' online postings in a course that comprised both project-based and non-project learning activities were coded and counted for knowledge construction, teaching, and social interaction moves using computer-mediated discourse analysis. Chi-square analyses found that the instructor's teaching discourse remained fairly consistent during project-based and non-project learning. Despite this, students' online discussions during project-based learning were characterized by more advanced levels of knowledge construction, where ideas were rationalized and integrated into plausible solutions. In contrast, students' online postings outside project-based learning rarely moved beyond the lower levels of information sharing and idea exploration. Based on these results, guidelines for designing and facilitating online project-based learning are presented and discussed.

1. Introduction

Asynchronous discussion forums, chat, and other computer-mediated tools facilitate social exchanges between instructors and students during online learning. Researchers such as Garrison, Anderson, and Archer (2001) and Gunawardena, Lowe, and Anderson (1997) have proposed that knowledge is constructed through these social exchanges when new and deeper understandings are found in students' online discourse. These authors also posit that advanced levels of knowledge construction occur when students demonstrate the ability to formulate, evaluate, and apply new ideas to resolve issues. However, empirical evidence suggests that such advanced levels of knowledge construction rarely occur during actual asynchronous online discussions (e.g., Kanuka & Anderson, 1998; Kanuka, Rourke, & Laflamme, 2007; Meyer, 2003).

Project-based learning is used in higher education to develop students' competencies for problem solving, group work, and self-management (Collis, 1997). It involves students in generating, evaluating, and implementing project ideas (Blumenfeld et al., 1991; Howard, 2002). Garrison (2007) posited that such learning activities could be influential in advancing students' knowledge construction level, and some empirical studies of online project-based learning lend suggestive support to this idea (e.g., Aviv, Erlich, Ravid, & Geva, 2003; Thomas & McGregor, 2005). Following on this proposition, therefore, the present study examined if students' engagement in project-based learning was related to their demonstration of advanced knowledge construction during asynchronous online discussions. Graduate students' online postings in a course that comprised both project-based and non-project learning activities were coded and counted using computer-mediated discourse analysis (Herring, 2004). Chi-square analyses revealed that the instructor's teaching discourse remained fairly consistent during project-based and non-project learning. Despite this, students' online discussions during project-based learning were characterized by more advanced levels of knowledge construction where ideas were rationalized and integrated into plausible solutions. In contrast, their online postings outside project-based learning rarely moved beyond information sharing and idea exploration. The features of project-based learning that may have supported advanced levels of student knowledge construction in this case are discussed. In conclusion, we present and discuss guidelines for designing and facilitating online project-based learning.

2. Theoretical background

2.1. Models of online knowledge construction

The Interaction Analysis Model (IAM) of Gunawardena et al. (1997) was one of the earliest frameworks to characterize knowledge

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construction during online learning. The IAM was developed through qualitative analysis of an online debate involving 554 participants in a distance education conference. Debate leaders posted a motion and facilitated a week-long session during which the participants posted comments affirming or arguing against the motion. Analysis of the patterns and themes that emerged through these participants' online discourse led the researchers to posit that knowledge construction involves five phases: (1) Sharing and comparing of information, (2) exploration of dissonance, (3) negotiation of meaning, (4) testing and modification, and (5) application. Gunawardena et al. assumed that the purpose of social interaction in this educational context was to produce new knowledge and understanding. Learners co-construct knowledge by moving from "lower to higher mental functions" (p. 415); that is, they first share and compare information before negotiating, testing, and applying ideas collaboratively.

Garrison, Anderson, and Archer (2000) studied the use of computer-mediated communication in higher education contexts and proposed that the quality of learning is determined by students' ability to construct deep understanding through sustained critical discourse. Subsequently, Garrison et al. (2001) proposed that knowledge construction occurs in four stages, through which learners develop and confirm meaning: (1) Triggering event, (2) exploration of ideas, (3) integration of ideas, and (4) resolution of dilemma. According to this model, triggering events occur within the shared world of an online learning community, whereas the exploration, integration, and resolution of ideas may occur either privately or collaboratively. In Garrison et al.'s (2001) conception, students construct knowledge by toggling between private reflection and social reflection within the online learning community.

Gunawardena et al.'s (1997) model is more oriented toward collaborative knowledge construction within groups, while Garrison et al.'s (2001) model can be used to address both individual and collaborative knowledge construction. However, both models assume that the quality of students' knowledge construction becomes more advanced in the latter stages. This assumption also underlies studies by Scouller (1998) and Osman and Herring (2007) that claim that "deep learning" occurs when students demonstrate the ability to generate, evaluate, and apply ideas to solve problems, while their learning remains "surface" if they merely exchange information.

A number of studies of online discussion in higher education contexts have applied Gunawardena et al. (1997) or Garrison et al. (2001)'s models. Consistently, such studies have found that students' knowledge construction seldom progresses beyond the exchange of information. Several studies based on the five-phase protocol of Gunawardena et al. (1997) found that at most 6.5% of students' discussion posts were at Stage 5—Application (Kanuka & Anderson, 1998; Osman & Herring, 2007). Studies using Garrison et al.'s (2001) rubric have also concluded that the majority of students' online discussion posts involved the exploration of ideas, while at most 10% of these attained the highest level of Resolution (Garrison, 2007; Garrison et al., 2001; Kanuka et al., 2007; Meyer, 2003; Vaughan & Garrison, 2004). These somewhat discouraging findings lead naturally to the question: How can the quality of students' knowledge construction through online discussions be improved? Specifically, what can be done to facilitate student attainment of the higher levels of integration, resolution, and application?

2.2. Project-based learning and advanced levels of knowledge construction

Garrison (2007) claimed that online learning tasks that guide students to propose, explore, and synthesize solutions could positively impact the quality of students' knowledge construction. Project-based learning is a methodology that has the potential to support this proposition. Projects are non-routine activities undertaken within a specific time frame to meet defined objectives (Gray & Larson, 2008). During project-based learning, students resolve issues or dilemmas by designing, critiquing, and evaluating concrete artefacts or products (Blumenfeld et al., 1991; Howard, 2002). This method embodies John Dewey's conception of "learning by doing" (Barron et al., 1998), as students are responsible for planning and implementing their ideas and solutions. It engages them to ask questions, search for information, brainstorm, design, and test alternative solutions (Blumenfeld et al.), which, as hypothesized by Garrison (2007), are activities that could help them better construct knowledge.

Two studies of online learning in higher education contexts suggest that project-based learning could be favourable for facilitating student knowledge construction. Aviv et al. (2003) found that close to 58% of students' discussion posts were associated with the testing of solutions related to their project work online. Thomas and McGregor (2005) found that close to 50% of student messages were associated with the exploration and implementation of ideas during the initial stages of a project; this increased to 92% by the end of the project. The results of these studies are promising, but they are in the minority; most other studies of online project-based learning have largely focused on the dynamics of online collaboration (e.g., Bernard & Lundgren-Cayrol, 2001; Lou, 2004; Paulus, 2005). Therefore, there is a need for focused investigation of how project-based learning is related to students' knowledge construction during online discussions.

3. Research question

Given the background presented above, the following research question was explored in this study:

RQ: What is the relationship, if any, between students' participation in project-based learning and their construction of knowledge at advanced levels during online discussions?

Following the definitions of Garrison et al. (2001) and Gunawardena et al. (1997), knowledge construction in this study is understood as the process whereby students undertake social exchange with their instructor or peers in order to create and apply new understandings that resolve dilemmas and/or issues they are facing. The closer the students are to resolving their issues, the more advanced their level of knowledge construction.

It is hypothesized that advanced levels of knowledge construction will characterize students' online discourse when they engage in project-based learning. The proportion of advanced knowledge construction discourse should also be larger when they engage in project-based learning as compared to non-project learning, because project-based learning, by its nature, engages students in the exploration and development of solutions to issues and dilemmas.

4. Methodology

4.1. Subjects

The subjects were the 17 students (13 females and 4 males) enrolled in an online graduate course conducted at a large Midwestern university in the USA over 12 weeks during the summer semester of 2007. The course was a graduate elective offered by the university's School of Education that taught the design of e-learning courseware using the computer applications Macromedia Flash and Dreamweaver. Instruction for this fully online course took place entirely through an asynchronous online discussion forum hosted on Google Groups. This course was purposively selected for the study, in that it comprised both project-based and non-project learning activities. Internal validity threats due to subject characteristics (Fraenkel & Wallen, 2003) could be controlled, as the same group of students was involved in both the project-based and non-project learning activities.

4.2. Study context

The non-project component was carried out during the first five weeks of the semester. Students learned software skills for web development by completing a series of individual competency tasks (e.g., setting file restrictions on a webpage and making a cascading style sheet) that accounted for 20% of their course grade. Through instructor-produced screencast movies, students reviewed demonstrations of software procedures and applied these to produce the required technical artefacts. These tasks were specific and close-ended, in that students either met or did not meet the technical specifications set by the instructor. They did not require extensive brainstorming, designing, or exploration of alternative solutions—some of the core characteristics of project-based learning as defined by Blumenfeld et al. (1991). The non-project component also involved the instructor initiating online discussions of assigned readings to clarify issues related to theoretical principles of e-learning design.

In the course syllabus, the instructor emphasized the need for the class to share knowledge as a community. Accordingly, it was a class practice for students to post all web development questions on the GoogleGroups discussion forum. In addition to engaging in discussion with the instructor, students were also encouraged to share technical know-how with each other and to help each other resolve technical problems if they knew the solutions. As a consequence, even though they were completing tasks individually, students in the class engaged in knowledge construction through social interaction with both instructor and peers.

After practicing the technical skills needed for web development, students moved on to the project-based component of the course, which took place during Weeks 5–12. They worked on an individual design project that required them to develop e-learning courseware that addressed the learning needs of a self-selected target audience; this accounted for 80% of their course grade. The instructor structured the development process into six project milestones. Students submitted artefacts for critique and feedback by the instructor and peers at each milestone, as follows:

a) Week 5: Proposal describing target audience and instructional objectives of courseware.
b) Week 6: Proposal of evaluation plan and draft of mastery tests.
c) Weeks 7–8: Design paper prototype of courseware.
d) Weeks 9–10: Develop computer prototype.
e) Weeks 11–12: Conduct usability tests with at least three members of the target audience.
f) Week 12: Submit report of design rationales, usability testing results, and suggestions for product improvement, and then present the final product through a 30-minute synchronous web meeting with the instructor.

Students were individually responsible for conceptualizing, planning, and designing their e-learning courseware. The instructor continued encouraging students to share knowledge as a community by providing feedback on each others' work. At each project milestone, students uploaded artefacts onto a server space provided by the university and posted URL links on the Google Groups discussion forum for the instructor and their peers to access their work. The instructor and students then posted comments on the discussion forum to initiate discussions of pertinent issues.

The first author was an assistant instructor for the course; she primarily helped to provide feedback on students' e-learning products during the synchronous web meetings in Week 12. She did not participate in the online discussions; the instructor was wholly responsible for facilitating these and assigning grades for students throughout the course. The other authors were not involved in the teaching or administration of the course.

4.3. Data collection

The data for this study were messages posted on the course's Google Groups discussion forum from the beginning to the end of the course; all 419 messages were downloaded for analysis. To prevent bias during online discussion, the objectives of the study were not made known to the instructor or the students during the course. After obtaining Human Subjects clearance from the university, the instructor and students were provided with study information via email as per the approved procedure. The email informed subjects that the study involved analysis of their discussion posts and reporting of quantitative trends. Subject identity would be protected, as all posts were analyzed anonymously, and results were reported in aggregate. The email also included a section which sought signed consent to use quotations (with subjects' names changed to pseudonyms) from the messages downloaded. Signed consent was eventually obtained from four students and the instructor. Accordingly, examples of online discourse in this report are quoted only from these five subjects.

Although email and other modes of communication were used for issues where personal correspondence was needed, as a class practice, all communication related to web development, project issues, and class logistics occurred through the GoogleGroups discussion forum. The instructor explained that the forum should capture the collective knowledge of the class, and that both the instructor and students could learn more about web development by sharing problems and solutions. There was evidence of the instructor modeling this practice from the beginning of the course, when he posted and responded to all the help requests he received via other sources as a thread on GoogleGroups. A check with the instructor indicated that students complied well with his required practice within the first two weeks of the course, such that the frequency of him having to transfer their help requests from other communication media to the forum was minimized. For these reasons, we considered the forum posts adequate for capturing the knowledge construction interactions that occurred among the instructor and the students.

4.4. Data analysis

Computer-mediated discourse analysis is an approach that employs content analysis of recurrent language patterns to understand online behaviour (Herring, 2004). It was used in this study as an overarching framework to analyze discourse patterns in the Google Groups discussion threads. Specifically, a coding and counting approach was applied to derive relative frequencies of coding categories in the online discourse related to knowledge construction, and multiple raters were used to establish the reliability of the coding.

4.4.1. Unit of analysis

Rourke, Anderson, Archer, and Garrison (1999) stated that "thematic units" better capture the logic of a phenomenon than "syntactical units" such as sentences (p. 60). Paulus (2007), following Herring (1996), used the term *functional moves* to refer to the thematic units in computer-mediated discourse that serve different purposes or communicative functions. In this study, the functional move was the unit of analysis, and each message was broken down into its component functional moves.

4.4.2. Qualitative content analysis

In their Community of Inquiry (COI) model, Garrison et al. (2000) claim that three elements contribute to meaningful online learning experiences in a higher education context: Cognitive Presence, Social Presence, and Teaching Presence. Cognitive Presence reflects the quality of knowledge constructed by an online community; Teaching

Presence refers to how instructors sequence learning activities and facilitate learning; and Social Presence reflects how members in a community of inquiry project themselves personally. The model posits that Cognitive Presence (i.e., knowledge construction) needs to be supported by the latter two elements.

The COI model was adopted as a conceptual framework to understand knowledge construction in this study because it was specifically designed for online learning in higher education, similar to the context of this study. The Gunawardena et al. (1997) model was also considered but was not adopted, as it could only inform the coding of Cognitive Presence (in the sense of the COI model), but not Teaching Presence or Social Presence. In contrast, a number of studies using the COI model have validated coding schemes for Cognitive Presence, Teaching Presence, and Social Presence (e.g., Anderson, Rourke, Garrison, & Archer, 2001; Garrison, Cleveland-Innes, Koole, & Kappelman, 2006; Rourke et al., 1999). Gunawardena et al.'s model was developed out of the online discussions of conference participants and has also been used in the context of group projects (e.g., Paulus, 2007), different from the project undertaken by the participants in the present study. Thus, following the COI model, Knowledge Construction, Teaching, and Social Interaction moves were adopted as three broad categories of functional moves to be used in this study (see Table 1).

The Knowledge Construction moves were developed using the four stages of cognitive presence described in Garrison et al. (2001). In the COI model, cognitive presence describes the outcomes of students' knowledge construction that is primarily being facilitated through the teaching presence of instructors (Garrison et al., 2000). In this study, the instructor was the key person who facilitated students' project progress, which is consistent with the conception of the COI model. Therefore, the stages of cognitive presence were applied only to the students' discourse, similar to the approach adopted by other researchers (e.g. Kanuka et al., 2007; Meyer, 2003). During our initial data analysis, we also found students sharing general information about their projects that did not fall within Garrison et al.'s four levels. We therefore added an additional category, Level 0—Sharing Information (cf. also Osman & Herring, 2007).

The instructor's discourse was first coded for Teaching moves using two categories developed by Anderson, Rourke, Garrison and Archer (2001) for Teaching Presence: Direct Instruction and Facilitating Discourse. The critique and feedback of project artefacts were critical activities that took place after each milestone and affected the modifications students made to their projects. However, Anderson et al.'s coding scheme for Direct Instruction did not cater specifically to artefact design. Therefore, a third Teaching functional move—Feedback—was added. There were also instances of students engaging in peer instruction in this study, similar to the findings of Osman and Herring (2007) and Paulus (2007). These were coded using the three categories of Teaching moves, so that comparisons could be made between the Teaching discourse of the instructor and of the students.

`The discourse of the instructor and students was also coded for Social Interaction moves using the affective and interactive dimensions of Social Presence (Rourke et al., 1999). Both the students and instructor engaged in the expression of emotions, appreciation, and the exchange of social information. Like Paulus (2007), we also found it necessary to add a fourth category—Logistics—to cater to the context of this study. This was not broken down into sub-categories, as Logistics moves were uniformly associated with the coordination of various course logistics (e.g., the textbook and URLs for milestone submissions).

The coding protocol and the definitions of each category are listed in Table 1. The data were coded by the first author, and reliability of the coding protocol was established through a second rater, who is also the third author. All messages were re-coded by the second rater, and multiple rounds of negotiation were carried out until a Cohen's kappa of at least 0.75 was reached for all categories, as recommended by Rourke, Anderson, Garrison, and Archer (2001).

Table 1
Coding protocol.

Knowledge construction
1. Level 0—sharing of information—providing project information or personal opinions about readings
2. Level 1—triggering event—posing questions without evidence of idea exploration
3. Level 2—exploration of ideas—description of possible project ideas or attempts at problem solving but without attempting to justify ideas
4. Level 3—integration of ideas—connecting ideas to form preliminary solutions and showing ability to justify ideas
5. Level 4—resolution of ideas—resolving issues/problems or applying ideas to new situations
Teaching
1. Direct instruction—providing content information/recommendations
2. Facilitating discourse—asking questions or probing for further thoughts on an issue
3. Feedback—affirmation or critique of ideas
Social interaction
1. Socialize—appreciation/apologies/well wishes/social talk
2. Emotion—expressions of emotion or humor via repeated punctuation, capitalization, or emoticons
Logistics
1. Discussions about course logistics (e.g. deadlines and submission format)

4.4.3. Quantitative data analysis

The numbers of Knowledge Construction moves, Teaching moves, Social Interaction moves, and Logistics moves were first counted. A contingency table analyzing the Knowledge Construction moves by non-project and project-based learning activities was then constructed. To answer the research question, Pearson's chi-square analysis was used as a test for significant associations, following which 2×2 post-hoc analyses were conducted to interpret differences between cells with Bonferroni correction of alpha values (Huck, 2004).

The differences in the relative numbers of Teaching moves, Social Interaction moves, and Logistics between project-based and non-project learning could possibly influence students' Knowledge Construction moves. Therefore, these moves were broken down by project-based and non-project learning, following which significant associations were examined using Pearson's chi-square analysis.

5. Results

5.1. Distribution of functional moves

A total of 680 functional moves were coded. About 71% of these were student moves, while the rest were instructor moves. Of the student moves, about 39% were Knowledge Construction, about 30% were Social Interaction, and about 26% were Logistics moves, while Teaching moves accounted for only about 6% (see Table 2). Instructor moves, in contrast, were mostly related to Teaching (about 79%), while the rest were for Social Interaction and Logistics. These results show that peer instruction among students was marginal; the overwhelming majority of Teaching moves were produced by the instructor. Conversely, students were more engaged in Social Interaction, especially socializing, than the instructor was.

Analysis of Knowledge Construction moves revealed that the proportion of Level 1 and Level 2 moves combined (44.5%) was greater than that of Level 3 and 4 moves (28.8%). Students also engaged in substantial information sharing, in that Level 0 accounted for about one quarter of the Knowledge Construction moves.

5.2. Students' knowledge construction moves by project-based and non-project learning

Chi-square tests revealed significant association between students' Knowledge Construction functional moves and participation in project-based learning (see Table 3): χ^2 (4, N = 184) = 17.7, $p<0.01$, Cramer's V = 0.31. Level 3 appeared to be a major contributor to the

Table 2
Distribution of functional moves (n = 680).

	Student		Instructor	
	No.	%	No.	%
Knowledge construction				
Level 0—share information	49	10.3	–	
Level 1—triggering event	21	4.4	–	
Level 2—exploration of ideas	61	12.8	–	
Level 3—integration of ideas	39	8.2	–	
Level 4—resolution of ideas	14	2.9	–	
Sub-total	184	38.6	–	
Teaching				
Direct instruction	9	1.9	93	46.0
Facilitating discourse	2	0.4	25	12.4
Feedback	16	3.3	41	20.3
Sub-total	27	5.6	159	78.7
Social interaction				
Socialize	100	20.9	8	4.3
Emotion	41	8.6	17	9.2
Sub-total	141	29.5	25	13.5
Logistics	126	26.3	18	7.8
Total	478	100	202	100

differences, as the absolute value of its standard residuals was greater than two (Agresti, 2007). The contingency table was then broken down into 2×2 tables for post-hoc pair-wise comparisons using a Bonferroni corrected alpha of 0.036. This series of post-hoc analyses found significant differences between Level 3 and other levels of Knowledge Construction moves, as follows: with Level 0 (χ^2 (1, N = 88) = 16.21, $p < 0.001$); with Level 1 (χ^2 (1, N = 60) = 13.52, $p < 0.001$); with Level 2 (χ^2 (1, N = 100) = 15.08, $p < 0.001$); and with Level 4 (χ^2 (1, N = 53) = 8.16, $p < 0.01$). However, post-hoc analyses found no significant differences among Level 0, Level 1, Level 2, and Level 4.

5.2.1. Knowledge construction moves during project-based learning

During project-based learning, close to 37% of students' observed Knowledge Construction moves were associated with Level 3 or Level 4, as compared to only 9.3% during non-project learning (see Table 3). Level 3 moves were most often demonstrated when students attempted to justify their courseware design in relation to the needs of their target audience. For example, in the following message, Bob describes the difficulties some users are experiencing using his site to justify the proposed creation of tutorials, and in so doing, integrates the ideas of user difficulties and possible solutions:

> Bob: I have set up a moodle site for my business English classes … I included in the course introduction simple instructions on how to register, sign in for a class and get started but several students have either not been able to register or are having trouble knowing what to do. I would like to prepare some short tutorials for these students. *[Level 3—Integration of ideas]*

Table 3
Student knowledge construction moves by non-project learning and project-based learning.

		Move					
		Level 0: share	Level 1: trigger	Level 2: explore	Level 3: integrate	Level 4: resolve	Total
Non-project learning	Observed	19	8	22	1	4	54
	Expected	14.4	6.2	17.9	11.4	4.1	54.0
	% of total	35.2	14.8	40.7	1.9	7.4	100.0
	Std. residual	1.2	0.7	1.0	−3.1	0.0	–
Project-based learning	Observed	30	13	39	38	10	130
	Expected	34.6	14.8	43.1	27.6	9.9	130.0
	% of total	23.1	10.0	30.0	29.3	7.6	100.0
	Std. residual	−0.8	−0.5	−0.6	2.0	0.0	–
	Total functional moves	49	21	61	39	14	184

The instructor's questions and suggestions sometimes prompted students to articulate their design decisions in more depth, thereby demonstrating Level 3 moves. For example:

> Instructor: This project sounds like it has some possibilities.… Have you checked to see if there are existing tutorials on Moodle for users?
> Bob: I took your advice and looked around a bit for other moodle tutorials, etc. There are some good moodle resources but most of it is text rich. This could be a huge barrier for some of my learners. My feeling is though that a video presentation with the actual screens my students will be seeing will better facilitate the learning I am after. *[Level 3—Integration of ideas]*

The iterative design–feedback–refinement cycle involved in developing e-learning courseware continually engaged students to demonstrate Knowledge Construction moves. For example, the student, Bob, had rationalized that video tutorials were more effective for his learners. As he proceeded to develop his courseware, he realized he needed to resolve technical issues related to video production, which resulted in a Level 2 move where he explored ideas for doing so.

At times, students were able to indicate problem resolution through Level 4 moves, e.g.:

> Instructor: It also looks to me that the post-assessment will take a while to do.
> Jenny: I asked a co-worker to take the post-test assessment and they were able to understand it and complete it in about 10 minutes, so that shouldn't be too long (most of the questions are multiple-choice), though the screenshots make it look really long. *[Level 4—Resolve]*

Nevertheless, post-hoc pair-wise comparison of Level 3 and Level 4 moves found that the observed frequencies for Level 4 were still lower than expected during project-based learning.

5.2.2. Knowledge construction moves during non-project learning

During non-project learning, the observed frequencies of Level 0, Level 1, and Level 2 were each higher than expected in comparison to Level 3 (See Table 3). Students used Level 0 functional moves to update the instructor on their progress, e.g., "Here is my page … I'm still working on making it secure," and they made straightforward requests for help characteristic of Level 1 moves, e.g., "Do you have any suggestions for why I can't input a password in there?" Students also demonstrated Level 2 moves when they described their attempts at resolving problems with competency tasks, e.g., "I tried to update it by downloading PuTTy and Plink, but I have not had any luck." The occurrence of Level 3 moves was negligible, and Level 4 moves were also infrequent (see Table 3).

5.3. Teaching moves, Social Interaction moves, and Logistics moves of students by project-based and non-project learning

Chi-square analysis found no significant association between students' Teaching moves and their participation in project-based or non-project learning. Neither were students' Social Interaction moves significantly associated with their participation in project-based or non-project learning. However, as expected, the students produced significantly more Logistics moves during project-based learning (n = 80) than during non-project learning (n = 46): χ^2 (1, N = 126) = 9.17, $p < 0.001$. There were more occasions where they had to clarify submission procedures and requirements with the instructor during

Table 4
Instructor social interaction moves by student participation in project-based learning.

		Move		
		Emotion	Socialize	Total
Non-project learning	Observed	5	6	11
	Expected	7.5	3.5	11.0
	% of total	20.0	24.0	44.0
	Std. residual	−0.9	1.3	
Project-based learning	Count	12	2	14
	Expected count	9.5	4.5	14.0
	% of total	48.0	8.0	56.0
	Std. residual	0.8	-1.2	
Total functional moves		17	8	25

project-based learning. There were no instances of students clarifying course logistics with each other, however.

5.4. Teaching moves, Social Interaction moves, and Logistics moves of the instructor by project-based and non-project learning

From Table 2, it can be seen that about 66% of the instructor's Teaching moves were Feedback and Direct Instruction, e.g., "You have created some file called htaccess.htm. *[Feedback]* The file must be named: .htaccess. It begins with a period and must be spelled exactly this way." *[Direct Instruction]*. The instructor also used Facilitating Discourse to probe students' thinking, e.g., "will ALL your users be required to use MS Internet Explorer version xxx?" However, Facilitating Discourse comprised only 13.6% of instructor functional moves. Chi-square analysis found that the instructor's teaching discourse did not differ significantly regardless of whether he was facilitating project-based or non-project learning. Thus the order of learning tasks did not appear to have affected his teaching style.

Similarly, there were no significant differences in the instructors' Logistics moves across project-based and non-project learning. However, significant differences were evident in his Social Interaction moves: χ^2 (4, N = 25) = 4.59, p < 0.05, Cramer's V = 0.43. The instructor's use of Socialize appeared higher than expected during non-project activities, while his use of Emotion was higher than expected during project-based learning (see Table 4). This could be because non-project learning was carried out during the beginning of the semester, when it was important for the instructor to break the ice with students through social talk, e.g., "I'm glad to hear that your Dreamweaver site is working smoothly for you." As the instructor became more familiar with students around the time project-based learning started at Week 5 of the semester, he became comfortable with displaying more of his persona, for example, through the use of emoticons, e.g., "OK, my values are on the table, in case you hadn't noticed. :-)" However, these results should be interpreted with caution, as 50% of the cells had expected values of less than five.

6. Discussion

This study analyzed whether and how students' participation in project-based learning in a graduate course on the design of e-learning courseware was related to how they constructed knowledge during asynchronous online discussions. Messages posted by the instructor and students in the course's Google Groups discussion forum were analyzed as functional moves with respect to Knowledge Construction, Teaching, Social Interaction, and Logistics. Using a computer-mediated discourse analysis approach (Herring, 2004), these functional moves were coded and counted, and their frequencies were analyzed in relation to students' engagement in project-based or non-project learning. Chi-square analyses found that the students' Teaching moves and Social Interaction moves remained fairly consistent throughout the course. However, there was significant association between students' Knowledge Construction moves and their participation in project-based learning. Post-hoc 2×2 chi-square analyses found that observed frequencies of Level 3 moves were higher than expected when students were engaged in project-based learning. These results support our hypothesis that higher levels of Knowledge Construction moves would be demonstrated during project-based learning.

Of course, it is possible that the differences in the stages of knowledge construction found in this study reflect influences other than the incorporation of project-based learning alone. Learning environments are complex, with many variables in addition to task type that may affect learner behavior. For example, the ordering of non-project learning before project-based learning may have had an effect on the distribution of Knowledge Construction moves, with higher-level moves occurring during the second half of the course because of a deepening or increasing focus of attention as the course progressed towards its conclusion—and the due date for completed projects to be submitted—over time. While this may have been a factor, by its very nature, project-based learning calls for integration, resolution, and application, and as the results of this study show, the task design of each course component indeed engaged students in different types of learning. Moreover, the frequency of different Knowledge Construction moves varied according to task type, while Social Interaction and Logistics moves remained relatively constant throughout the semester, as did the Instructor's teaching style. Taken together, these factors strongly suggest that task variation—project-based vs. non-project learning—contributed to the significant variation in Knowledge Constructions levels found in this study.

In the following section, we discuss specific features of the project-based learning methodology employed in this study that could have supported advanced levels of student knowledge construction.

6.1. Project milestones

Aviv et al. (2003), Murphy (2004), and Kanuka et al. (2007) found that structured activities resulted in higher levels of knowledge construction during online discussions. In the present study, project milestones were structured to move students systematically from design to development and evaluation of their e-learning courseware. Students were required to articulate and justify design and development strategies as they completed each milestone, which could have directed them towards Level 3 functional moves during online discussions. In addition, the need to meet project deadlines also motivated them to focus on problem solutions. This finding is consistent with Lawson's (2006) observation that project deadlines often drive designers to resolve problems.

6.2. Design problems

Project activities in this study engaged students in the design of solutions for instructional problems faced by an actual set of learners. Alexander (1964) defined design as a process of achieving fit between the form and context. Students in this study were challenged to achieve this fit at every project milestone—that is, their courseware topic and design had to demonstrate adequate fit with a specific target audience's needs. This might have directed students towards justifying their design decisions, which could have increased the frequency of Level 3 moves during project-based learning. During non-project activities, in contrast, students were completing technical tasks such as setting up a cascading style sheet and setting restricted access to a web folder. These tasks could be completed successfully through straightforward application of technical procedures. This could have led students to demonstrate more Level 1 and Level 2 moves, as their emphasis was on finding a correct answer, rather than evaluating alternative ideas.

6.3. Project artefacts

In this study, students articulated their design ideas through various artefacts such as paper prototypes, drafts of mastery assessments, and computer prototypes. These artefacts externalized students' current state of knowledge (Blumenfeld et al., 1991) and functioned as what Scardamalia and Bereiter (1994, p. 270) termed "knowledge objects." Students also received feedback and queries from the instructor when they shared their project artefacts, which stimulated them to respond in the form of Knowledge Construction moves as they attempted to justify or reconsider their design propositions. Students encountered what Rowe (1987) described as "wicked problems" when designing artefacts, so called because students could be led down different solution paths, depending on how they defined the problem. In this study, problems resolved at one project milestone often presented students with a new set of problems at the next. Multiple cycles of artefact evaluation may have contributed to students' continual production of Knowledge Construction moves.

6.4. Limitations of project-based learning to advance knowledge construction

An interesting finding in this study was that observed frequencies of Level 4 were lower than expected when compared to Level 3 during project-based learning. Garrison (2007, p. 66) found that "progression requires direction." Advanced levels of knowledge construction during online discussion need to be facilitated consciously by instructors (Meyer, 2003). In the present study, the instructor's facilitation style did not appear to vary between project-based and non-project learning. Functional moves such as Feedback and Facilitating Discourse may be especially important for moving students from Level 3 to Level 4 during project-based learning. The instructor did use these functional moves, but a higher magnitude of use may be needed to advance students' Knowledge Construction moves to Level 4. Shea (2006) found that both Direct Instruction and Facilitating Discourse contributed positively to students' learning and sense of community. However, the types of Teaching moves that can impact Level 4 moves need to be further studied, as these relationships are not well understood in the current literature.

7. Guidelines for implementing online project-based learning

Based on the above discussion, we propose the following four guidelines for the implementation of online project-based learning to foster knowledge construction:

7.1 Assign students a design problem: Design problems engage students in evaluating the fit between problem solutions and contextual needs. The problem should be suitably complex to warrant iterative design–feedback–refinement cycles.

7.2 Structure project milestones to facilitate knowledge construction: Project milestones should guide students to progress from idea exploration to problem solutions.

7.3 Have students articulate their learning through the development of learning artefacts: The production of artefacts helps students concretize their knowledge construction process. It can also be used to stimulate social construction of knowledge when accompanied by feedback and critique from instructors and peers.

7.4 Facilitate towards Level 4: Instructors need to assess students' stages of knowledge construction and use appropriate functional moves to advance students beyond their current levels of knowledge construction.

8. Limitations and directions for future research

This case study was limited to a single e-learning design course and 17 graduate students. It would be important to seek to replicate its findings in a number of online classes engaged in different types of projects, including in classes where project-based learning activities occurred early, rather than later, in the course. This would help determine what effect, if any, task order has on levels of knowledge construction.

This study found Level 0 moves in terms of Knowledge Construction; thus our coding scheme diverged slightly from Garrison et al.'s (2001) existing rubric. While the presence of what we identified as Level 0 moves, 'sharing of information,' may have been influenced by the class practice instituted by the instructor of communicating all class-related matters through Google Groups, more data related to students' interaction with instructors and peers from other communication modes such as email need to be collected through interviews or surveys in future studies. This would provide a more comprehensive understanding of the knowledge construction activities of students, which, in this study, were limited to what was posted in the asynchronous discussion forum. Such additional sources of data might also provide insight into students' perceptions of how factors such as task order, instructor facilitation, and social interaction helped or hindered their knowledge construction.

Finally, the students in this study were engaged in individual projects and deferred to the instructor for technical feedback, as reflected, for instance, in the fact that they exhibited Social Interaction moves rather than Teaching moves when commenting on each others' work. For this reason, the results of this study may not fully reflect the dynamics of knowledge construction in group contexts. The differences in knowledge construction processes that take place in group and individual projects need to be studied. In addition, differences between blended and fully online courses should be investigated, in order to enable generalization about online knowledge construction patterns across varying contexts, as well as articulation of context-specific patterns, with the ultimate goal of aiding instructors in identifying successful strategies for developing advanced levels of knowledge construction through online discussions.

9. Conclusion

The results of this study provide evidence that online project-based learning has the potential to provide students with a structure that supports knowledge construction at advanced levels during asynchronous online discussions. The four guidelines recommended in this study aim to address the challenges faced by instructors with respect to facilitating knowledge construction through online discussions to promote deep learning.

References

Agresti, A. (2007). *An introduction to categorical data analysis.* Hoboken, NJ: John Wiley & Sons, Inc.

Alexander, C. (1964). *Notes on the synthesis of form.* Cambridge, MA: Harvard University Press.

Anderson, T., Rourke, L., Garrison, R. D., & Archer, W. (2001). Assessing teaching presence in a computer conference context. *Journal of Asynchronous Learning Networks*, *5*(2), 1−17.

Aviv, R., Erlich, Z., Ravid, G., & Geva, A. (2003). Network analysis of knowledge construction in asynchronous learning networks. *Journal of Asynchronous Learning Networks*, *7*(3), 1−23.

Barron, B., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, T., Zech, L., et al. (1998). Doing with understanding: Lessons from research on problem and project-based learning. *Journal of Learning Sciences*, *7*, 271−311.

Bernard, R. M., & Lundgren-Cayrol, K. (2001). Computer conferencing: An environment for collaborative project-based learning in distance education. *Educational Research and Evaluation*, *7*(2), 241−261.

Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, *26*(3/4), 369−398.

Collis, B. (1997). Supporting project-based collaborative learning via WWW environment. In B. Khan (Ed.), *Web-based instruction* (pp. 213−219). Englewood Cliffs, NJ: Educational Technology Publications.
Fraenkel, J. R., & Wallen, N. E. (2003). *How to design and evaluate research in education.* New York: McGraw-Hill.
Garrison, D. R. (2007). Online community of inquiry review: Social, cognitive, and teaching presence issues. *Journal of Asynchronous Learning Networks*, *11*(1), 61−72.
Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2–3), 87−105.
Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking and computer conferencing: A model and tool to assess cognitive presence. *American Journal of Distance Education*, *15*(1), 7−23.
Garrison, D. R., Cleveland-Innes, M., Koole, M., & Kappelman, J. (2006). Revisiting methodological issues in transcript analysis: Negotiated coding and reliability. *The Internet and Higher Education*, *9*(1), 1−8.
Gray, C. F., & Larson, E. W. (2008). *Project management.* New York: McGraw-Hill.
Gunawardena, C., Lowe, C., & Anderson, T. (1997). Analysis of a global online debate and the development of an interaction analysis model for examining the social construction of construction. *Journal of Educational Computing Research*, *17*(4), 397−431.
Herring, S. C. (1996). Two variants of an electronic message schema. In S. C. Herring (Ed.), *Computer-mediated communication: Linguistic, social, and cross-cultural perspectives* (pp. 81−108). Amsterdam: John Benjamins.
Herring, S. C. (2004). Computer-mediated discourse analysis: An approach to researching online behavior. In S. A. Barab, R. Kling, & J. H. Gray (Eds.), *Designing for virtual communities in the service of learning* (pp. 338−376). New York: Cambridge University Press.
Howard, J. (2002). Technology-enhanced project-based learning in teacher education: Addressing the goals of transfer. *Journal of Technology and Teacher Education*, *10*(3), 343−364.
Huck, S. W. (2004). *Reading statistics and research.* Boston, MA: Pearson Education Inc.
Kanuka, H., & Anderson, T. (1998). Online social interchange, discord, and knowledge construction. *Journal of Distance Education*, *13*(1), 57−74.
Kanuka, H., Rourke, L., & Laflamme, E. (2007). The influence of instructional methods on the quality of online discussion. *British Journal of Educational Technology*, *38*(2), 260−271.
Lawson, B. (2006). *How designers think.* Oxford: Elsevier.
Lou, Y. (2004). Learning to solve complex problems through between-group collaboration in project-based online courses. *Distance Education*, *25*(1), 49−66.
Meyer, K. A. (2003). Face-to-face versus threaded discussions: The role of time and higher-order thinking. *Journal of Asynchronous Learning Networks*, *7*(3), 55−65.
Murphy, E. (2004). Recognizing and promoting collaboration in an online asynchronous discussion. *British Journal of Educational Technology*, *25*(4), 421−431.
Osman, G., & Herring, S. C. (2007). Interaction, facilitation, and deep learning in cross-cultural chat: A case study. *The Internet and Higher Education*, *10*(2), 125−141.
Paulus, T. M. (2005). Collaborative and cooperative approaches to online group work: The impact of task type. *Distance Education*, *26*(1), 109−123.
Paulus, T. M. (2007). CMC modes for learning tasks at a distance.*Journal of Computer-Mediated Communication*, *12*, article 9. Retrieved from http://jcmc.indiana.edu/vol12/issue4/paulus.html
Rourke, L., Anderson, T., Archer, W., & Garrison, D. R. (1999). Assessing social presence in knowledge in computer conferencing. *Journal of Distance Education*, *14*(2), 50−71.
Rourke, L., Anderson, T., Garrison, D. R., & Archer, W. (2001). Methodological issues in the content analysis of computer conference transcripts. *International Journal of Artificial Intelligence in Education*, *12*, 8−22.
Rowe, P. (1987). *Design thinking.* Cambridge, MA: MIT Press.
Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences*, *3*(3), 265−283.
Scouller, K. (1998). The effect of assessment method on students' learning approaches: Multiple choice question examination versus assignment essay. *Higher Education*, *35*, 453−472.
Shea, P. J. (2006). A study of students' sense of learning community in online learning environments.*Journal of Asynchronous Learning Networks*, *10*(1) Retrieved from http://www.sloan-c.org/publications/jaln/v10n1/v10n1_4shea_member.asp
Thomas, R. W., & McGregor, S. K. (2005). Online project-based learning: How collaborative strategies and problem solving processes impact performance. *Journal of Interactive Learning Research*, *16*(1), 83−107.
Vaughan, N., & Garrison, D. R. (2004). Creating cognitive presence in a blended faculty development community. *The Internet and Higher Education*, *8*, 1−12.