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Integrating emerging topics through online team design in a hybrid communication networks course: Interaction patterns and impact of prior knowledge

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Abstract

An important challenge in the introductory communication networks course in electrical and computer engineering curricula is to integrate emerging topics, such as wireless Internet access and network security, into the already content-intensive course. At the same time it is essential to provide students with experiences in online collaboration, which is common in the engineering workplace, and to allow both on-campus and distance learning students to actively and jointly participate in class activities in hybrid on-campus/distance education course offerings. To address these challenges in the introductory communication networks course at Arizona State University, the authors have developed an online team design project in which students collaborate via a team website on a design project related to an emerging communication networks topic. The online team design project was evaluated with a thematic analysis of the interactions on the team websites, topic-specific pre- and posttests, and an attitudinal student survey. It was found that the online team communication was to a large extent devoted to managing the team and the project and that the students had overall very positive attitudes toward the project. Both students with lower and higher levels of prior project-related knowledge achieved approximately the same learning gain in terms of increased scores from pretest to posttest in the project.

Keywords: Asynchronous communication; Communication networks course; Emerging topics; Hybrid learning; Network security; Synchronous communication; Team design

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1. Introduction

An introductory communication networks course that introduces the principles of the five layer Internet model and the responsibilities, functioning, and interactions of the protocols and mechanisms at the individual layers is commonly offered in electrical and computer engineering programs. The introductory communication networks course is typically quite content-intensive due to the vast amount of material on the basic operating principles of communication networks, such as the Internet. On the other hand, the rapid and widespread proliferation of the Internet has and is giving rise to a plethora of emerging new topics and issues in the area of communication networks. Examples of such topics and issues include the increased use of wireless access to the Internet, the growing need for security in networking, and the increased transport of multimedia content over the Internet. Given the key importance of such emerging topics and their popularity among students, it is desirable to integrate them into the introductory networking courses to provide the students with some basic knowledge of these topics. However, the integration of these new topics into the introductory course is very challenging due to the abundance of material on the basic networking principles.

The widespread proliferation of the Internet has made online collaboration of engineers that are located in different places common practice in the engineering workplace. Providing students with online team collaboration experiences that they can later apply in the engineering workplace becomes therefore increasingly important.

Another important issue that the introductory networking course in the Department of Electrical Engineering at Arizona State University (ASU) is facing and that many other courses and institutions are facing is the trend toward hybrid course offerings that cater simultaneously to traditional on-campus students as well as off-campus distance learners. The distance learners in these classes typically receive the class video via web-streaming over the Internet and complete all assignments and tests off-campus. While distance learning brings the distance learners flexibility in terms of when and where to complete the course work, it also limits their active involvement in the class community and the peer-to-peer student mentoring, which are vital components of a successful class and learning experience (Rovai, 2002).

2. Background and related work

This section first provides a brief overview of the background, existing models, and approaches to online team design projects, which fall into the realm of collaborative education (Felder & Brent, 1994; Michaelsen, Knight, & Fink, 2004; Pimmel, 2003; Roberts, 2004; Smith, 2004), and more specifically into the domain of Asynchronous Learning Networks (ALNs) (Latchman, Salzmann, Gillet, & Kim, 2000; Mason, 2000; Vonderwell, 2003). Then the two areas of research most closely related to the present study, namely the area of online team projects in hybrid courses and the area of enhancing introductory communication networks courses are discussed.

Collaborative learning in general and asynchronous learning networks in particular have been successfully employed for education in a number of domains (Schrum & Hong, 2002), for example communication (Pena-Shaff, Martin, & Gay, 2001; Pena-Shaff & Nicholls, 2004), computer sciences (Calogne, 2002; Jehng & Chan, 1998), engineering (Asif, 2004; Crow, Startett, Olejniczak, & Sudhoff, 2000; Felder & Brent, 2001), as well as mathematics and physics (Malley & Scanlon, 1990;

Oktac, 2004). Systems for technologically supported discussions, either synchronously or asynchronously, are characterized by the exchange of typed messages of its members (Weisskirch & Milburn, 2003). With the removal of spatial and/or temporal boundaries by connecting the individual group members over the Internet a wider body of students can learn from each other's ideas and viewpoints (Wegerif, 1998; Wilson & Whitelock, 1998) and the writing of these ideas fosters understanding (Rada & Hu, 2002; Wheeler & McDonald, 1998).

The learning process–which in general can be viewed in terms of several different mental and social interaction models–takes place by integration of new information taking into consideration prior knowledge with selection, organization, and integration of the newly gathered information for the individual learner. Collaborative learning requires that learners organize their freshly obtained knowledge in such a way that the resulting output of one learner becomes consumable input for another learner (Spiro, Feltovich, Jacobson, & Coulson, 1991), which may increase the cognitive load of individual learners (Sweller, 1994).

In general, students benefit from collaborative learning (or group learning) as the merging of different opinions and concepts fosters the learning process (Hammond, 2000; King, 2002). Without loss of generality, it can be assumed that each group member contributes to the learning outcome of the entire group, yet the learning of the individual group members depends on the feedback from the other group members. It is thus important to consider not only the individual learner–learner and learner–teacher interactions, but also the group characteristics and dynamics to adequately capture all underlying processes (Palloff & Pratt, 1999). For the social group processes, the well-known four phases identified by Tuckman (1965), namely (i) forming, (ii) storming, (iii) norming, and (iv) performing can be applied (Brace-Govan, 2003; McCreary, 1990). It was found, however, that online group processes may skip the storming phase (Johnson, Suriya, Yoon, Berret, & La Fleur, 2002). In addition to Tuckman's model, other modified stages of group processes were identified in, e.g., McCreary (1990) and Gunawardena, Lowe, and Anderson (1997).

An initial effect in group discussion is blocking (Diehl & Stroebe, 1991), which in verbal brainstorming requires the students to coordinate idea generation and communication and requires them to do so in a timely manner. Blocking in asynchronous electronic discussions, however, is widely eliminated (Gallupe, Bastianutti, & Cooper, 1991; Hiltz, 1997), as is the pressure to respond in a timely fashion or at an adequate time (Kaye, 1989). A different group effect is social loafing, which causes individual group members to make less effort than they would for tasks that can be individually observed (Diehl & Stroebe, 1987; Latan, Williams, & Harkins, 1979). Social loafing can be viewed as outcome of a social comparison process. In general, social comparisons can be either upward or downward (Festinger, 1954). In order to facilitate the positive outcome of social comparison processes in such a way that performance is increased, upward social comparison should be supported and downward social comparison minimized. A common approach to facilitate the upward social comparison is to make the individual contributions of the participants comparable see e.g., Michinov and Primois (2005) and Paulus, Legett, Dzindolet, Coskun, and Putman (2002) and the references therein. Interactions among students can take different forms, (see, e.g., Garrod & Anderson, 1987) and may be affected by the electronic communication medium. For instance, students who are shy tend to be more active in online discussions (Palloff & Pratt, 1999), but also misunderstandings are increased due to the lack of visual cues (Berge, 1997).

As in traditional classes, the control, feedback, and intervention from the instructor (also referred to as the moderator) is needed and the instructor needs to provide incentives for participation (Wilson &

Whitlock, 1998). In collaborative learning environments the goal is to foster learning primarily through the collaboration of the students while social cues present in the classroom are unavailable (Rovai, 2000). The role of the instructor is in the process of being closer examined (Anderson, Rourke, Garrison, & Archer, 2003; Garrison, Anderson, & Archer, 2000). In particular, the interactions between learners and instructor were examined (Kamin, Glicken, Hall, Quarantillo, & Merenstein, 2001) and general tasks and responsibilities of online instructors qualitatively defined (Coppola, Hiltz, & Rotter, 2002; Goodyear, Salmon, Spector, Steeples, & Tickner, 2001). In general, it is important to consider the influence of this teaching presence (Anderson et al., 2003) on the outcome of the learning process, as well as the social interactions among learners, as it may have undesirable effects such as too early convergence among learner's opinions or social contracting with sub-optimal outcomes (see, e.g., Huebscher-Younger & Narayanan, 2003). Non-premature convergence of the group members towards a correct understanding, however, is a desirable part of the learning process (Roschelle, 1992). Such creative processes, however, seldom follow a linear path; it is far more likely that several iterations are necessary (Welch, 1999) before convergence commences.

The two areas of (i) online team projects in hybrid classes, and (ii) enhancing introductory communication networks courses, which are the areas most closely related to the present study, are reviewed next. A fairly large body of research has examined various forms of hybrid course offerings that combine on-campus classes and online class activities from a wide variety of perspectives; selected representative studies from this area are the following. Latchman, Salzmann, Gillet, and Bouzekri (1999) have studied the technologies for hybrid class offerings. Benbunan-Fich and Hiltz (2002) compared the impact of the course level (undergraduate vs. graduate), course type (engineering vs. humanities), and gender on the course grades and the perceived learning of students in three different types of courses, namely entirely fact-to-face, hybrid, and entirely online. It was found that the students in the hybrid and entirely online courses earned higher grades and that graduate students in hybrid classes perceived the highest learning gains. Matthews (2002) proposes and discusses the conceptual issues of a three component hybrid instruction that combines well-prepared, high-quality prerecorded online multimedia lectures, spontaneous real-time online lectures, and face-to-face meetings. Rovai (2001) compared the sense of community that doctoral education students developed in two different types of hybrid courses: (1) a course where the students are widely dispersed in terms of location and meet annually for a 5-day on-campus instructional period, and (2) a course where the students live in the vicinity of the campus and meet monthly for one day on campus, but also in informal group study sessions and at social gatherings. It was found that the students in the second type of course developed a stronger sense of community, especially in terms of the community components spirit and trust.

The present study considered a hybrid course of the form where the on-campus students attend the class lectures on campus and the distance learners do not come to campus but rather receive the class lectures through video web-streaming over the Internet. Both groups of students jointly worked on online team design projects. Hybrid course offerings with online team projects have been examined in a few studies. In order to provide students with online collaboration experiences, Barchilon and Baren (1998) developed an online engineering design project in which undergraduate students from Arizona State University-East and Temple University, Philadelphia, collaborated. The qualitative evaluation of the project found that the project was successful in making the students aware of the challenges and complexities of online communication. Dufner, Kwon, and Rogers (2001) developed a project where system design and decisions systems students from two remote university campuses collaborated online on a complex team project task. Dufner et al. (2001) conducted a pilot study to examine the student

attitudes and the preferences for the online communication tools (e.g., e-mail, chat, group discussion). The students had overall positive attitudes toward the project, especially the online discussion, and the tool preferences varied widely among the different teams. Lawrence-Slater (2002) developed and assessed a team project in which information and communication technology students from different universities (located in Melbourne and Wollongong, Australia, and Singapore) collaborated online to produce an electronic journal presenting individual research papers that relate to a single theme. Three surveys conducted at the beginning of the class project, in the middle of the class, and at the conclusion of the project asked for the students' expectations, attitudes, and experiences through open-ended questions. It was found that the students in Singapore who were predominantly full-time workers embraced the online activities more than the Australian students, who were predominantly full-time students. Swigger, Alpaslan, Brazile, and Monticino (2004) examined how the cultural perspectives and GPAs of student teams consisting of one student from a U.S. university and one student from a Turkish university related to successful completion of a collaborative online computer programming project. The study found that a number of cultural perspective attributes, such as harmony (striking a balance in life and work) and future-oriented (being primarily concerned with future consequences), and their combination in the team members were important for predicting team performance. The present study is complementary to this existing literature in that it examines the interaction patterns and the impact of lower and higher prior project-specific knowledge in an online team design project that is part of a hybrid (on-campus/web-based video streaming) communication networks course.

Instruction in the area of communication networks has been of continuing interest for over a decade, (see for instance Marten & Yavatkar, 1992) and has recently received increased interest (Kurose, Liebeherr, Ostermann, & Ott-Boisseau, 2002). Several types of enhancements to introductory communication networks courses have also been studied. One type is the integration of laboratory exercises with real or simulated networking equipment (see for instance Comer, 2004; Hill, Carver, Humphries, & Pooch, 2001; Liebeherr & ElZarki, 2003; Mengel & Bowling, 1995). Another type is the integration of programming and design projects, (see for instance Huang, 1995), which is also pursued in this study; however in the context of an online team design project in a hybrid course.

3. Team design project structure and procedures

This section describes the developed team design project in detail. First, the documents (materials) that were prepared to assign the project and to assess the student learning and attitudes are described. Also the set-up of the online facilities for the team work and communication is described. This section concludes with a description of the team formation and of the procedure for executing and supervising the project.

The team design project was developed for the Spring 2004 offering of the EEE459 Communication Networks course at ASU. This class is a hybrid course in the sense that both on-campus students and distance learners are enrolled. The course is taught to the on-campus students in a studio classroom and recorded in the form of video. The class video is made available after each class via web streaming to the distance learners, who never visit the campus.

The developed team design is described in the context of this course, but it should be noted that the basic structural principles of the team design project appear applicable to a wide variety of courses. The instructor selected four emerging topics from the area of Internet security and wireless Internet access for

the projects, specifically the topics (1) Internet firewalls, (2) Internet purchasing, (3) wireless LAN, and (4) wireless LAN security.

3.1. Materials

The instructor prepared four main documents for administering and assessing the project, namely the project assignment, the test, the team project evaluation form, and the attitudinal survey. Only the project assignment and the team project evaluation form are needed to include the project in a class and are made available to the students via the course website. The test and the attitudinal survey were used for evaluating the project. The project assignment and the test were topic specific, i.e., the instructor developed four different versions of these documents, one for each project topic. The team project evaluation form and the attitudinal survey were the same for all topics/groups.

The project assignment document presented the students with the context for their design task and their specific design problem. The project assignments were posed in the context of the team having been hired as consultants by a business operating out of a home office for solving a specific networking design problem. The assignment document for the Internet firewall topic is provided as an exemplary assignment document in Appendix A. The assignment asks the team to prepare a consultation report that addresses three main points. First, the report should survey the available options for solving the design problem along with their advantages and drawbacks. Based on this survey of the available options the team should select one option as their recommended solution and justify their choice. Second, the report should explain the basic mechanisms and principles employed in the surveyed solution options. Third, the report should provide the specific solution set-up for the design context, including, if appropriate, diagrams of the design solution.

The topics were specified to provide sufficient freedom for collaborative idea generation, problem solving, and learning processes, as is generally a recommended strategy for collaborative learning (Danchak & Kenyon, 2002; Hackman & Vidmar, 1970; Michaelsen et al., 2004). Importantly, the project assignment asked the team members to conduct the entire team design project and all communication relating to the project exclusively online via the team page on the class website. The assignment also noted that the grade for the team project, which accounted for 15% of the total course grade (as specified in the class syllabus), would be based on the contributions toward the consultation report on the team web page.

The test was designed to assess the students' knowledge of the basic concepts and principles of the different topic areas at the level covered in introductory networking texts, (e.g. Kurose & Ross, 2003), which was the required text for the class. The test consisted of ten problems that were presented in the form of true/false, multiple choice, fill in the gaps, and short answer items. Both the pretest and the posttest for a given topic were obtained by randomly sequencing the ten items on the test for the topic and randomly ordering the various answer choices (on multiple choice items).

The team project evaluation form asked the students to briefly describe the tasks that they fulfilled on their team, to self-reflect on what they have learned from participating in the online team design project, and to rate (grade) the performance of each of their fellow team mates. Specifically, the students were asked to grade their peers on three attributes: contribution to the final report, effective online communication, and on-time completion of assigned tasks, using a five-point (A—excellent to E—extremely poor) rating scale. In addition, the students were asked to provide open comments on the performance of their peers.

The anonymous attitudinal survey consisted of 16 survey items (listed in Table 5). Each survey item consisted of a statement about the team design project accompanied by a five-point Likert-type rating scale on which the students indicated their level of agreement with the statement from strongly agree to strongly disagree. In addition, the students were asked for open-ended comments on the aspects they liked the best/the least about the online team design project, and ways to improve the project.

The construct validity of the evaluation instruments (tests and attitudinal survey) was assessed in accordance with Aiken (1997) through the judgment of subject matter experts and a pilot with a sample of the target audience. Also, the internal consistency of the tests and attitudinal survey were analyzed. This analysis revealed Cronbach alphas in the range from .81 to .85 for the tests and a Cronbach alpha of .88 for the attitudinal survey, which indicates a high level of internal consistency.

3.2. Team page on class website

The instructor created a team page for every team on the class website. The class website was set up on an electronic content delivery and management platform (Blackboard), which provided class information and online communication facilities (e.g., discussion board, e-mail list) for the entire class. Each team page offered an electronic asynchronous discussion board, a synchronous online chat facility, and a file exchange facility. A given team page was accessible only by the members of the corresponding team (as well as the instructor).

Several other integrated commercial systems are available to setup the web page and team page infrastructure, such as Lotus or WebCT. In general, it is important that the online communication system has a clear interface and makes the exchanged messages easily accessible (Kear, 2001; Wang, 2001). The main criterion for adopting the Blackboard learning system for the team design project was that the students were familiar with the system as it is commonly employed in ASU courses, avoiding a cognitive overload due to unfamiliarity with the communication infrastructure (Sweller, van Marrienboer, & Paas, 1998).

3.3. Team formation

The team design project was conducted in the Spring 2004 EEE 459 Communication Networks class, in which 33 on-campus students and 4 distance learners were enrolled. The instructor split the class randomly into eight teams (5 five-student teams and 3 four-student team). The small group sizes of 4–5 students were selected in accordance with (Caspi, Gorsky, & Chajut, 2003; Felder & Brent, 1994; Johnson & Johnson, 1994). To facilitate the integration of the distance learners with the on-campus students, the distance learners were distributed over the groups. In particular, there were four teams with one distance learner each (and also four teams without any distance learner). Two teams worked independently on each of the four project topics.

One limitation of this study is the small number ($N=4$) of distance learners. The hybrid on-campus/web-based distance learning class program offering is in its infancy at Arizona State University and is projected to grow significantly in the near future. Due to the small number of distance learners this study did not allow for a quantitative evaluation of the interaction patterns, learning gains, and attitudes of the group of distance learners, or a quantitative comparison with the group of on-campus students. Instead, only anecdotal results are reported for the distance learners. It should be noted that despite the low current distance learner enrollment–or especially in the current infancy stage of the web-based program

with low enrollment–it is important to develop and investigate instructional techniques that allow for joint activities by on-campus and distance learning students. These joint activities may help to foster a vibrant class community encompassing both on-campus and distance learning students, which in turn may help in making the spatially isolated distance learners feel as part of the class community and help in their learning and retention.

3.4. Procedure

The team design project was assigned in the 6th week of the semester and was due 7 weeks later (whereby the semester had a total of 16 weeks). These dates were chosen to ensure that the students had acquired a basic overview of the principles of communication networks by the time the project started and also to avoid a conflict with the final exams at the end of the semester.

The project was assigned through the posting of the project assignment documents and a document detailing the composition of the teams on the online class website and a corresponding e-mail alert. The on-campus students were administered the pretest corresponding to their project by the instructor during the regular on-campus class session on the morning of the day of the project assignment. The pretest was administered to the distance learners by their proctors, who also administered the regular class exams. The instructor reinforced the online team design project assignment by presenting an overview of the common context of the design projects in class, namely that they all related to the business operating out of the home office. The instructor also pointed out that all the teams had been hired as consultants by the same business and that their design solutions should be focused on the specific problem assigned to the group. For example, the wireless LAN team was to focus on the set-up of the wireless LAN, while the security aspects in the wireless LAN were to be addressed by the wireless security team.

While the online team design project was underway the instructor regularly monitored the electronic exchanges on the individual teams' pages. The instructor provided positive feedback for teams that were making good progress and provided pointers and clarifications for teams that encountered difficulties. Every 2 weeks the instructor evaluated the student work and encouraged on-task behaviors. Throughout the project, the instructor emphasized that the entire project and its related communication should be conducted exclusively online using the team web page infrastructure.

On the due day of the project, the instructor collected the consultation reports from the teams through the digital drop box facility on the class website. The posttest and the anonymous attitudinal survey were administered to the on-campus students by the instructor during the regular class session on the due day and to the distance learning students by their proctors. The students e-mailed their team project evaluation reports to the instructor by the project due date. The reports were used in conjunction with the analysis of students' contributions to the online communication and the completed consultation report as a basis for grading the student's performance on the project.

4. Evaluation

This section presents the evaluation of the online team design project. To capture the multifaceted nature of the project, the type and frequency of the online interactions on the asynchronous discussion board and synchronous chat, the learning gain (difference between pretest and posttest scores), and the student attitudes are considered.

4.1. Pretest performance and blocking into lower and higher level of prior knowledge

The students had a mean score of $M=2.89$ (with standard deviation SD = 1.41) out of a maximum of 10 points on the pretest. For the analysis of the project the students were blocked according to the pretest score into students with a lower level of prior domain specific knowledge (pretest score of 3 and lower) and students with a higher level of prior domain specific knowledge (pretest score of 4 and higher). There were 28 students with a lower level of prior knowledge and 9 students with a higher level of prior knowledge. This ability blocking, which was adopted in consultation with subject matter experts, reflects that a relatively small number of the students had prior exposure to and some level of prior knowledge of the emerging topics. On the other hand, the majority of the students had no or very little prior exposure to these new topics.

4.2. Coding of online interactions into themes

The participants of synchronous and asynchronous study groups exchange messages with different content, style, and use of language, to name a few. The coding of the exchanged messages requires that (i) the level on which to encode the message content has been determined and (ii) a coding model is defined. Rourke, Anderson, Garrison, and Archer (1999), for example, identified five different levels or units for further analysis, namely proposition, sentence, paragraph, theme, and message. The *theme* level was adopted for this evaluation, as it allows for the consideration of each *single thought unit or idea* within a message, whereby a single posting on the discussion board or a single message in the chat can be comprised of multiple themes. More specifically, to analyze the type and frequency of the online interactions a commonly used coding scheme (Brewer, 2004; Cavalier, Klein, & Cavalier, 1995; Hall et al., 1988; Klein & Schnackenberg, 2000), which is given in Table 1, was employed.

The cognitive interactions encompass all themes that relate to working on the project topic and to engaging in the technical aspects of the topic. The group process interactions encompass the project management, which includes clarifying the scope of the topic and the scheduling of the project tasks. Also, the themes relating to managing the team, including the assignment of individual tasks to the

Table 1
Coding scheme for themes in online student interaction (adapted from Brewer, 2004)

Code	Thematic content
0	Sum of all general themes
0.1	General off-topic content (e.g., weather, traveling)
0.2	Technical problems (e.g., Internet connectivity)
1	Sum of all cognitive interactions
1.1	Discussing (e.g., elaborating, giving information, summarizing)
1.2	Asking (e.g., expressing need for elaboration)
1.3	Answering (e.g., answering, clarifying)
1.4	Challenging (e.g., correcting, voicing opinion)
2	Sum of all team process interactions
2.1	Managing the project (e.g., topic clarification, scheduling)
2.2	Managing the team (e.g., task delegation)
2.3	Encouraging others (e.g., motivational statements)
2.4	General comments on the project (e.g., overall comments)

individual team members, fall under the team process interactions. On the other hand, the themes relating to the actual work on the topic and individual project tasks fall under the cognitive interactions.

The asynchronous student interaction was recorded from the discussion board postings and the synchronous student interaction was recorded from live online chats. In general it was observed that the student communication relied more on the asynchronous communication mode, as only three groups held chat sessions. In the following the asynchronous and synchronous student communication are evaluated separately.

4.3. Frequency and type of online communication

Table 2 reports the average number of themes posted per student during the entire duration of the project on the asynchronous discussion board and the corresponding standard deviation. The following are considered (i) the average over all students, and (ii) the average over the students with a lower level of prior knowledge, which is compared with the average of students with a higher level of prior knowledge.

From considering first the results over all students (Overall column), it is observed that the large majority of the themes related to team process interactions (code 2), which accounted for approximately two-thirds of the total number of generated themes. About a third of the themes related to cognitive interactions (code 1), and approximately 4% were general themes (code 0). A closer inspection of the three main code categories reveals that more than half of the team process themes are related to managing the team (code 2.2), e.g., assigning subtasks to individual team members and accepting or declining the responsibility for these tasks. Approximately 39% of the team process themes related to managing the project (code 2.1), e.g., interpreting the requirements and establishing due dates. Within the cognitive interaction category, most themes were created for discussing topic-related issues (code

Table 2
Mean and standard deviation of number of themes generated by a student during the entire project in asynchronous discussion board

Code	Total $N=37$		Low prior knowledge $N=28$		High prior knowledge $N=9$	
	M	SD	*M*	SD	*M*	SD
0	0.81	1.18	0.71	1.15	1.11	1.27
0.1	0.51	0.84	0.36*	0.62	1.00	1.22
0.2	0.30	0.81	0.36	0.91	0.11	0.33
1	6.30	7.79	6.82	8.05	4.67	7.09
1.1	4.14	5.07	4.57	5.36	2.78	3.99
1.2	1.22	2.61	1.54	2.91	0.22	0.67
1.3	0.43	0.87	0.32	0.61	0.78	1.39
1.4	0.51	1.04	0.39	0.83	0.89	1.54
2	14.35	8.52	15.39	8.87	11.11	6.74
2.1	5.57	3.98	5.96	4.26	4.33	2.83
2.2	7.49	4.45	7.93	4.69	6.11	3.44
2.3	1.11	1.24	1.29	1.33	0.56	0.73
2.4	0.19	0.46	0.21	0.50	0.11	0.33
Total	21.46	14.16	22.93	14.16	16.89	13.99

*Denotes significant difference at $p<.05$ level.

1.1), followed by the posing of questions (code 1.2), the answering themes (code 1.3), and the challenging themes (code 1.4).

Overall, these results indicate that the online communications was used to a large extent to manage the team and project and to a lesser extent to converse about the technical aspects and issues arising when working on the project tasks. From these results and the detailed inspection of the theme content the authors conclude that the students worked on their designated project tasks to a large degree independently and used the asynchronous communication primarily for group coordination. These results are consistent with the recent observations by Schellens and Valcke (2005).

Comparing the numbers of themes per student from the students with lower and higher levels of prior knowledge it is observed that there are generally large differences. However, the variabilities in these numbers are also large, as illustrated by the fairly large standard deviations. Due to these high variabilities, the differences between the two groups of students are generally not statistically significant. An exception is the difference in the general off-topic themes (code 0.1). An analysis of variance (ANOVA) revealed that the students with higher prior knowledge generated a statistically significantly larger number of general off-topic themes compared to their lower prior knowledge counterparts, $F(1,35)=4.39$, $\mathrm{MSE}=0.64$, $p=.04$. Although the other differences do not reach the commonly considered $p<.05$ significance level, they do indicate interesting tendencies. Overall, there is a tendency for the students with lower prior knowledge to generate a larger total number of themes, which appears to indicate that these students put a lot of effort into the project. In particular, the students with lower prior knowledge tended to initiate more discussions on technical issues and to ask more topic related questions, whereas the students with higher prior knowledge tended to give more answers and posted more themes that challenged the postings of other team members. Overall, these observed tendencies appear to indicate that the students with a lower level of prior knowledge made an effort to be involved and contribute to the design project by initiating discussions on the technical aspects of the project topic and asking questions relating to these technical aspects. The students with higher levels of prior knowledge complemented the efforts of the students with lower prior knowledge by providing more answers and challenges/corrections. These results appear to suggest pairing up students with lower and higher prior knowledge in the teams, which needs to be evaluated in detail in future research.

Table 3 reports the average number of themes generated per student in the synchronous chat over all the students that participated in the chat sessions. The total number of themes generated by a student during the online chats is quite high compared to the number of themes for the discussion board. It should be noted here that the exchanges in chats are typically very short messages that provide a brief statement about a theme, whereas the postings on the discussion board are typically much longer and elaborate on a theme in more detail. The composition of the types of chat messages is similar to the composition of the discussion board postings in that group process interactions were the largest category, followed by cognitive and general interactions. It is interesting to note however, that the general themes account for a relatively large fraction of approximately 23% of the themes compared to the relative small fraction of about 4% in the discussion board postings. This seems to be an indication of the highly dynamic nature of the chat sessions where the topic can steer away from the project topic to off-topic themes and back to the topic very quickly. It may be helpful if the team appoints a moderator (which the instructor may suggest in the project assignment) that keeps the chat focused on one theme at a time.

An anecdotal result relating to the distance learners enrolled in the class was that the students in the groups with an off-campus distance learner typically exchanged more off-topic themes to get to know each other personally and to maintain these personal relationships. The students in the groups without

Table 3
Mean and standard deviation of number of themes generated by a student during the entire project in synchronous chat

Code	Chat $N=12$	
	M	SD
0	16.67	26.59
0.1	12.33	8.77
0.2	4.33	5.28
1	27.33	13.22
1.1	12.83	6.62
1.2	6.83	5.97
1.3	6.42	5.16
1.4	1.25	1.71
2	29.33	13.98
2.1	14.33	15.07
2.2	11.67	10.71
2.3	0.92	1.00
2.4	2.42	2.97
Total	73.33	41.41

any distance learner, on the other hand, knew each other personally from the class meetings on campus and consequently exchanged significantly fewer off-topic themes.

Fig. 1 shows a plot of the number of generated themes in the asynchronous discussion for the three main categories, namely general themes (code 0), cognitive interaction themes (code 1), and team process interaction themes (code 2) as a function of the project day.

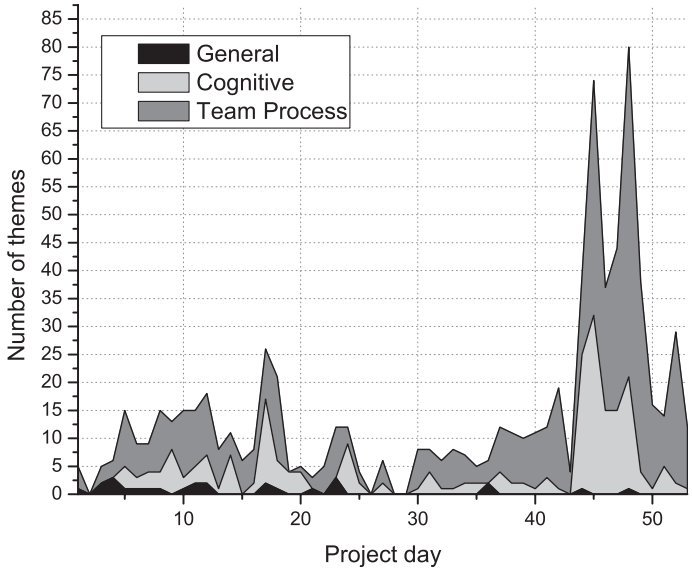

Fig. 1. Number of generated themes per day (from all $N=37$ students) as a function of project day for the three main theme categories, namely general themes (code 0), cognitive interaction themes (code 1), and team process interaction themes (code 2).

The plot shows that at the very beginning of the project, the general themes, mainly used to get acquainted with each other in the online environment, and the group management themes dominated. The cognitive interactions dealing with the technical aspects and issues of the project topic began around the fourth day of the project. Overall, there was a fairly high level of interactions during the first 18 days of the project, followed by a period of fairly low activity until around day 36, and then a pronounced increase and very high level of activity over the last 7 days of the designated project time (plus 4 days extension to make up for Internet outages caused by an e-mail worm around the due date). This result appears to corroborate the earlier observation that the online communication was primarily used for group management, i.e., for delegating the various subtasks to the individual team members at the beginning of the project and for coordinating the compilation of the outcomes of the work on the individual subtasks toward the end of the project. The technical work on the project topic appears to have been mostly conducted by individual students in isolation during the low activity period on the discussion board.

4.4. Learning gain

Table 4 reports the mean pretest and posttest scores, as well as the mean learning gain, which is defined as the difference between the posttest score and the pretest score. These results are considered for the students with lower and higher levels of prior knowledge and averaged over all students.

A paired sample *t*-test for the overall pretest and posttest scores revealed that the difference between these scores, and thus the learning gain, is statistically significant, $t(36)=8.90$, $p<.01$. Next, an ANOVA revealed that the students with a higher level of prior knowledge achieved significantly higher scores on the posttest ($M=7.89$) compared to their counterparts with a lower level of prior knowledge ($M=5.41$), $F(1,35)=8.54$, MSE=4.90, $p=.01$. Interestingly, an ANOVA also revealed that the learning gains were almost identical for the students with lower and higher levels of prior knowledge, $F(1,35)=0.00$, MSE=4.68, $p=.99$. These results indicate that the difference in knowledge levels that existed between the students with lower and higher levels of prior knowledge at the outset of the project was essentially preserved. Both groups of students achieved about the same improvement in mastery of the basic principles of their respective topic areas. This result is encouraging in the sense that both students with lower and higher levels of prior knowledge can gain about the same improvement of mastery from the project. At the same time the result is disappointing in the sense that the students with lower levels of prior knowledge were not able to achieve mastery levels similar to the higher prior knowledge students at the conclusion of the project.

Table 4
Mean pretest score, posttest score, and learning gain (=posttest score − pretest score) for students with lower and higher levels of prior knowledge and averaged over all students

	Overall $N=37$		Low prior knowledge $N=28$		High prior knowledge $N=9$	
	M	SD	*M*	SD	*M*	SD
Pretest	2.89*	1.41	2.29	0.85	4.78	1.09
Posttest	6.01*	2.43	5.41**	2.36	7.89**	1.62
Learning gain	3.12	2.13	3.13	2.28	3.11	1.69

* Denotes significant difference at $p<.01$ level between pretest and posttest scores.
** Denotes significant difference at $p=.01$ level between low and high prior knowledge students.

Table 5
Scores for survey statements from all $N=37$ students

Survey statement	Mean M	Std. Dev. SD
I enjoyed working in a team.	3.88	0.86
I learned a lot in this project.	4.12	0.70
Working with others simulated real life job settings.	4.03	1.08
I benefited from working with others during the project.	4.09	0.77
As a team, we generated better ideas than we would have done as individuals.	4.09	0.68
The project improved my ability to function on a team in a productive manner.	3.97	0.92
I enjoyed the opportunities to interact with others.	3.94	0.83
The number of people in my team was optimal.	3.88	0.82
I would like to engage in team activities in the future.	3.94	1.00
During the project, it was important to me that every team member made a significant contribution to the project.	4.45	0.62
In future team activities, I would prefer to work for points based exclusively on the overall team performance.	3.06	1.03
In future team activities, I would prefer to work for points based exclusively on my own performance.	3.15	1.06
Overall, this was a worthwhile project.	4.27	0.67
I liked that the team project was conducted exclusively in an online environment.	2.94	1.22
I felt comfortable using the online communication tools.	3.73	1.01
The ability to review discussion board postings and chat archives helped me to learn better.	3.21	1.08
Total	3.80	0.54

Another important observation from Table 4 is that the overall mastery level of the content as assessed by the posttest, was with approximately 60% only moderately high. This appears to be due to the students having put most emphasis on parts 1 and 3 of the project assignment, namely the survey of the available solution options for the design problem and the setup of the recommended solution (see Appendix A), whereas part 2 of the assignment, namely the review of the functioning of the underlying mechanisms in the solutions, received relatively less emphasis, as was reflected in the submitted team consultation reports. Also, after settling on the overall solution strategy, the team may have delegated part 2 of the assignment to one member who researched the underlying mechanisms while the other team members did not sufficiently familiarize themselves with that material. The improvement of the mastery of the knowledge of the underlying mechanisms of the topic area is an important direction for future research on the team design project. One strategy could be to require a minimum length of the response to part 2 of the assignment in the consultation report. A strategy to facilitate that all team members become familiar with the underlying mechanisms could be to have the team give a presentation of the consultation report to class, whereby a randomly selected team member could be chosen for the presentation of each part of the report. (Of course, the distance learners would need to be integrated into the presentation, either by presenting via a two-way audio connection or synchronous chat.)

4.5. Attitudinal survey

The students' responses to the survey items were scored by assigning a score of 5 for strong agreement, 4 for agreement, 3 for neither agreement nor disagreement, 2 for disagreement, and 1 for

strong disagreement. The mean scores from all $N=37$ students for the 16 survey statements and the corresponding standard deviations are given in Table 5.

Overall the students were mainly in agreement with the positive survey statements on the survey, as indicated by the overall mean score of 3.80 across all students and survey items. The highest rated item on the survey was the statement related to the importance of every team member contributing significantly to the project with a mean score of $M=4.45$ indicating strong to very strong agreement. The second and third highest ranked items underscore that the students found the project worthwhile ($M=4.27$) and that they had learned a lot from the project ($M=4.12$). The next highest ranked items indicate that the students benefited from working in teams ($M=4.09$), generated better solution ideas as a team than as individuals ($M=4.09$), and felt that the team work simulated real life job situations ($M=4.03$). The lowest ranked item was the statement on the project having been conducted entirely online with a mean score of $M=2.94$, indicating that the students were indifferent toward the online aspect of the project. Interestingly, Table 5 shows that the students had nearly equal levels of agreement with receiving grade points based on individual performance ($M=3.15$) or group performance ($M=3.06$). This indicates that it may be a good policy to combine and equally weigh individual and group grade points.

Table 6 reports the three most frequently constructed responses for each of the three open-ended questions on the attitudinal survey. As observed from the table, approximately 38% of the students liked the subject matter (selected topics) of the project the most. Approximately one quarter of the students liked the network system design and practical nature of the team project. Interestingly, five students indicated that they enjoyed the online interaction in the project the most. Note here that there were 4 distance learners who most likely liked this aspect of the project very much.

A related anecdotal result from interviews with distance learners was that the distance learners overwhelmingly agreed that it is very important for them to be integrated with the on-campus students in a joint class community and that the team design project was from their perspective highly successful in achieving this integration. The distance learners noted that through the project

Table 6
Most frequently constructed responses to the three open-ended questions ($N=37$ students, multiple answers allowed)

Question and 3 most frequent answers	Number of students
What did you like the best about this team project?	
Subject matter ("hot" topics, relevance to Internet users)	14
Project work (design of network system, practical relevance)	9
Online interaction	5
What did you like the least about this team project?	
Completely online project	17
Online communication with group members	8
Coordinating group work online	6
Please suggest modifications/improvements to this team project.	
Project work face to face (entirely/as complement to online work)	13
More detailed problem statements	5
Blackboard system improvements	3

they were able to establish personal relationships with on-campus students and that these personal relationships enabled them to successfully engage in informal peer-to-peer mentoring. The distance learners also noted that the peer-to-peer mentoring was primarily related to the class material covered in the regular lectures (and not to the design project) and that this peer-to-peer mentoring helped them to complete the class successfully.

Returning to the results of the open-ended survey questions, Table 6 indicates that close to 46% of the students noted that they liked the online aspect of the project the least (which is consistent with the low mean score for the corresponding survey statement). In addition, the students expressed that the communication with group members, as well as group coordination and workload distribution among group members was complicated due to the online nature of the project. This is corroborated by the suggestions made by approximately 35% of the students to conduct the team project entirely in face-to face meetings or to complement the online interactions with face-to-face meetings. Students indicated that especially in the beginning of the project they would have preferred to at least get to know each other face-to-face. One lesson learned from this online project is thus that it would be preferable to have face-to-face meetings of both the on-campus students as well as the distance education students on the teams at the beginning of the project, provided the location and schedule constraints of the distance learners allow for it. Alternatively it would be worthwhile to explore to which extent personal websites of the students with a picture, short biography, and some personal information (e.g., hobbies) could alleviate the perceived need for social interactions. Another suggestion for improvement was to use the discussion board to work towards a bulleted slide presentation, instead of a cohesive consultation report, as bulleted slides could be easier to exchange and discuss over the discussion board.

5. Conclusion

An online team design project has been developed and evaluated to address the integration of emerging topics into an introductory communication networks hybrid class while providing students with online collaboration experiences and allowing for the joint participation of on-campus and distance learning students. Teams of four to five students worked jointly via a team page on the class website on design projects relating to emerging wireless Internet access and Internet security topics. The thematic analysis of the online team interactions revealed that a large portion of the interactions was devoted to team and project management, and that students with low prior knowledge tended to ask more questions, whereas students with higher prior knowledge tended to provide more answers. This suggests to strive to pair students with lower and higher levels of prior knowledge in the project topic area in teams. The analysis of pretest and posttest scores revealed that both students with lower prior knowledge and students with higher prior knowledge achieved approximately the same learning gain and that the mastery level of the underlying mechanisms of the project topic was moderate, which is an exciting topic for future research. The attitudinal survey results indicated that the students had overall highly positive attitudes toward the project and perceived the project to be worthwhile and to have learned a lot. The students were least enthusiastic (indifferent attitudinal rating) about the online aspect of the project.

There are several exciting avenues for future research. One important direction is to investigate strategies for increasing the mastery level of the underlying mechanisms of the project topic while at the same time reducing the difference in mastery after project completion between the students with lower and higher levels of prior knowledge. Also, increasing the student interest in the online aspect of the team design project is an interesting and worthwhile topic for future research. One strategy could be to reinforce the importance of online collaboration experiences for the engineering workplace throughout the project by incorporating an industrial liaison. The industrial liaison could be a recent graduate of the class who is engaged in online collaboration in his/her workplace and reports to the class on his/her online collaborations through asynchronous presentations and/or interactive chat sessions. Another important avenue is to develop and evaluate strategies for fostering vibrant online class communities that integrate both on-campus and distance learning students. Some strategies that may be helpful in this regard and could be interesting topics for future research are the following: (1) Assigning homework problems (that may be more complex and involved than the regularly assigned problems) to teams to foster peer mentoring on the concepts covered in class. (2) A weekly or biweekly synchronous chat session for the entire class in which students and the instructor discuss questions on the class material, homework problems, etc., similar to the on-campus office hour. (3) Devote a few minutes in each class to present to the on-campus class the question/answer exchanges and discussions that the instructor has had asynchronously with the individual distance learners so the entire class can learn from these exchanges and to facilitate the integration of the distance learners and on-campus students into a unified class community.

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Appendix A. Sample of project assignment

Your group has been hired as a consultant by a business operating out of a home office to protect the network running in the home with a firewall. The network employs a mix of wired and wireless networking technology and connects a file server housing the files relating to the home business operations, a web server housing the website of the home business, six stationary PCs, five mobile laptops, four PDAs, and one printer in the home office. The home office business wants to prevent outside “hackers” from accessing the fileserver, PCs, PDAs, and laptops in the home office, while allowing outside customers to access the business website on the web server. Also, the business owners would like to allow their employees to access business-related websites on the Internet, but prevent employees from accessing auction and sports websites at the work place.

Please prepare a consultation report which outlines a solution to the network protection problem of the business owner. In your report please:

1) Describe the available options to address the protection problem, i.e., which products are available? What are the pros and cons (e.g., security loop holes) of these products? How much do they cost? Give a recommendation as to which solution should be acquired and installed.
2) Explain to the business owner, who does not know much about networking or security, how the mechanisms implemented in the available products (described in question 1) work.
3) Give an overview of the installation of the security solution, e.g., a diagram of how the various hardware and software components are connected, and explain how the solution is set up and configured.

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