

The Development of Social Capital in an Active, Blended, and Collaborative Engineering Class*

ROHIT KANDAKATLA^{1,2,**}, EDWARD BERGER^{3,4,5}, JEFFREY F. RHOADS^{4,5} and JENNIFER DEBOER^{3,4,5}

¹ Department of Electronics and Communication Engineering, KG Reddy College of Engineering and Technology, Hyderabad, TS, 500075, India. E-mail: rohit.kandakatla@kgr.ac.in

² Center for Engineering Education Research, KLE Technological University, Hubli, Karnataka, 580031, India.

³ School of Engineering Education, Purdue University, West Lafayette, IN, 47907, United States.

⁴ School of Mechanical Engineering, Purdue University, West Lafayette, IN, 47907, United States.

⁵ MEERCat: The Mechanical Engineering Education Research Center at Purdue, Purdue University, West Lafayette, IN, 47907, United States.

This paper presents results from a qualitative analysis that examined the role of pedagogical approaches, support resources, and classroom policies in developing social capital among students in a sophomore-level STEM course at a large Midwestern university. The course was pedagogically transformed by faculty into an Active, Blended, and Collaborative (ABC) learning environment with multiple avenues for students to create and develop social ties. The ABC learning environment encourages students to use their peers as a resource and work collaboratively, supported by digital resources, to enhance their learning experience in the course. Results from a thematic analysis show that the ABC learning environment mediated the development of cognitive, relational, and structural social capital. Students in the course built weak social ties by working with their peers on the online course blog, and they constructed strong ties through in-person collaboration, both inside and outside of the classroom. The collaboration outside of the classroom was also fostered by the departmental culture, demonstrating the complexity of students' network-building and the importance of the broader context beyond a single class intervention. The results illustrate how a learning environment can shape the social capital shared among students, with potential implications for how large, core STEM courses can be organized to support student peer networks.

Keywords: active learning; blended learning; collaborative learning; social capital

1. Introduction

The retention rate of students in Science, Technology, Engineering, and Mathematics (STEM) is one of the lowest by disciplinary area among undergraduate students in the United States [1]. In 2012, the President's Council of Advisors on Science and Technology predicted that the workforce in the US would experience a deficit of one million STEM college graduates in the next decade [2]. With less than fifty percent of STEM majors graduating in six years with the initial enrolled degree [3], a large number of researchers have focused on the reasons for student stop-out in undergraduate STEM education [4–8]. While the majority of this research has looked at the various factors affecting students' retention in the first year, the students in their second year, when they transition into core disciplinary classes, encounter different issues [9]. Factors affecting student persistence include the students' commitment to their academic major, satisfaction with faculty interactions, and commitment to their institution [9]. The students' commit-

ment to the institution stems from their everyday interaction with peers and faculty in both formal and informal settings [7], and in addition to social cohesion, peer and faculty interactions are important predictors of academic achievement [10, 11]. These observations have inspired many course and curriculum innovations to support student engagement with their academic community.

University course transformations in the last decade have largely focused on changes that allow for more students to interact with peers and faculty and, in turn, increase their social capital. For example, the Spanish university system recently adopted the European Higher Education Area (EHEA), which places peer-learning at the core of students' learning process [12]. The EHEA believes that the faculty should incorporate teaching strategies that consider dialogue and knowledge exchange as key elements and provide students with opportunities for collaborative work. The Active, Blended, and Collaborative (ABC) learning environment described in this study is one such example that incorporates pedagogical approaches and tools from multiple practices. It is shown to be effective for student outcomes, for example, offering colla-

** Corresponding author.

borative resources in both face-to-face and online spaces.

Over the past 10 years, the Dynamics course offered by the School of Mechanical Engineering at Purdue University has been transformed from a lecture-style course into an ABC learning environment. Instructors teaching the Dynamics course in this ABC learning environment, which came to be known as *Freeform*, provided multiple avenues for interactions as part of a collaborative learning culture. The learning environment includes students working together on in-class quizzes, collaborating with peers outside of the classroom, and helping each other asynchronously using a dedicated course blog [13]. As a result of these changes, the rate at which students receive non-passing D, F, and W grades (the DFW rate) has decreased, even when controlling for past academic performance, courses taken, and student demographics [14]. This ABC learning environment offers students many direct support resources in the form of solution videos or the course blog, but there are also multiple channels for the development of different kinds of social capital within the student body.

Social capital is defined as features of a social organization, such as a network, norm, or social trust, that facilitate coordination and cooperation for mutual benefit [15]. The literature on the role of social capital in higher education and its impact on students' academic performance continues to grow [16–20]. We contribute to this literature by studying social capital in a multi-resource, core STEM course. This paper examines how different types of social capital were fostered among students via different facets of the ABC learning environment. To do so, this study addresses the following research question:

RQ: In what ways does an ABC learning environment enable or hinder the development of different types of social capital among students in a core STEM course?

To address this question, thematic analysis was conducted on semi-structured interviews that were recorded with a subset of students who took the course in the spring semester of 2016. We used social capital theory to inform the results from the thematic analysis. These results provide engineering/STEM educators with an understanding of how innovative learning environments can play the role of a catalyst in developing different types of social capital among students.

In the Section 2, we situate the context by describing the course and academic setting in which the study was conducted. We introduce the social capital theory to highlight the nature of the ties built in a social network and discuss the different

dimensions of social capital that individuals can build in a network. This is followed in Section 3 by the research design, selection of sample, nature and process of data collection, and methods used for data collection. In the last two sections of the paper, we present (Section 4) the eight themes that emerged from qualitatively analyzing the student interviews. The results are followed by the discussion in Section 5 in which we map the various themes to the three dimensions of the social capital theory and talk about how the ABC learning environment fostered the development of social capital among students in the course. Limitations of the study and directions for future research are recommended while concluding the paper in Section 6.

2. Background

2.1 Study Context

Our study takes a deep qualitative look at a specific instantiation of an ABC environment (*Freeform*) that is applied to Dynamics, a core disciplinary course for Mechanical Engineering. Students in a *Freeform* classroom are provided with a range of learning resources that help them in developing their conceptual and procedural knowledge while they work on homeworks and study for the course exams [13]. Students use a hybrid Lecturebook that includes the course concepts, problems, and empty white space to enable active note taking. The *Freeform* classroom is blended; the course website provides access to a set of online videos that include examples of problems solved in the classroom, solutions to homework problems, and videos to help students visualize specific concepts of the Dynamics course. Collaborative learning is practiced in the classroom by encouraging students to work in groups to solve quizzes.

Outside of the classroom, students have access to an asynchronous online course blog which is one of the key resources for collaborative learning in the *Freeform* environment. Instructors expected homework assignments to be completed in a collaborative way and empowered students to work together, while exams were strictly individual assessments. Although students were encouraged to collaborate with their peers outside of the class, they were expected to submit the homework problems individually. The Dynamics course consisted of a large number of students in the classroom with each section having approximately 90 students. Dynamics is often considered to be a challenging bottleneck course that contributes to student stop-out in the second year of their academic program [21]. Fig. 1 summarizes the various resources available in the *Freeform* environment categorizing each of them as active, blended, or collaborative.

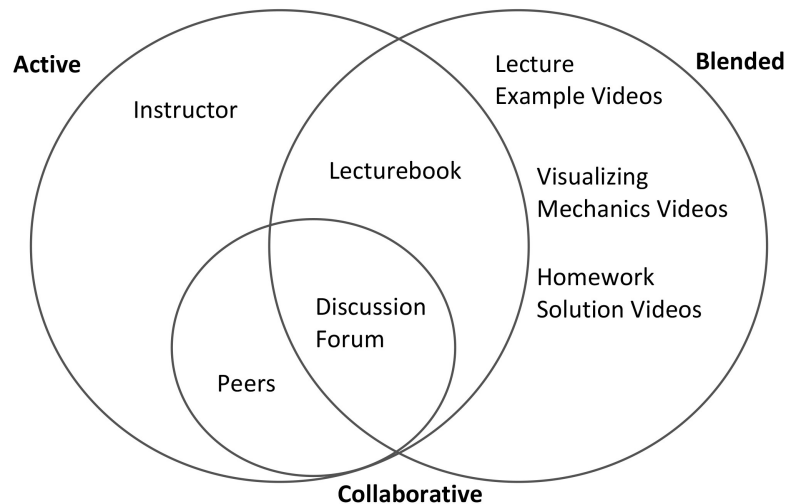


Fig. 1. Resources available in Freeform Dynamics that integrated ABC pedagogies.

2.2 Institutional Context

The culture of the academic unit in which this research took place is being studied in a related project, and the broader culture – particularly the academic experience of students – may simultaneously shape the social ties students build in this course. Department community members (faculty, staff, and students) have been interviewed and surveyed in a variety of ways in recent years, and analyses of those data provide a picture of the environment and social dynamics among the network of students.

The first contextual factor relevant to this paper is the intensity of the undergraduate program, which almost demands that the students collaborate actively. The academic program is described by all of the constituents using words such as ‘rigorous’ and ‘intense’, indicating that students experience serious demands on their time. Students describe a workload that essentially demands peer-to-peer collaboration in order to get all of the work done in an efficient way. This experience of intensity has been characterized using ritual theory [22], in which students share the experience of being part of a cohort undergoing an intense academic program. This ritual experience creates strong ties among the undergraduate population, and it also affects their decisions about how to get their work done. Undergraduate students report a peer culture that is highly collaborative, rather than competitive.

The identity of this cohort also manifests in terms of their help-seeking behaviors. We found that students primarily seek help synchronously from their peers (either face-to-face or by text/phone) and online resources, whereas faculty members and office hours are used very infrequently [23, 24]. Students provided a variety of reasons for this behavior, largely related to the inconvenience asso-

ciated with the time and location of instructor office hours. Nonetheless, students frequently turn to each other for both academic and social support in this academic program, and this symbiosis creates a general sense of strong ties within the student population.

2.3 Social Capital Theory

We use social capital theory as a conceptual framework to synthesize the findings in this paper. Social capital theory focuses on the resources that are ingrained in an individual’s social network and how access to, and the use of, these resources benefits the individual, which may include subsequent benefits throughout the network [25]. A social network relies upon ‘ties’ among individuals, and social capital is derived from accessing the expertise, support (emotional, physical, financial, etc.), or connections to other individuals via ties to them throughout the network. Social capital has three dimensions – structural, cognitive, and relational (Nahapiet & Ghoshal, 1998) – all of which function based upon the nature of social ties within the network.

2.3.1 The Formation and Types of Social Ties

Social networks are supported by a series of ties among individuals that collectively enable access to the resources embedded in the network. Ties can be characterized as direct (for example, ties among friends) or indirect, which tend to be developed with ‘friends of friends’. The directness and *strength* of the ties is a proxy for trust in the network, which in turn dictates the willingness to share resources among network members. In general, stronger ties within a social network are advantageous [25], because strongly-tied individuals share valuable resources more freely. Strong ties among indivi-

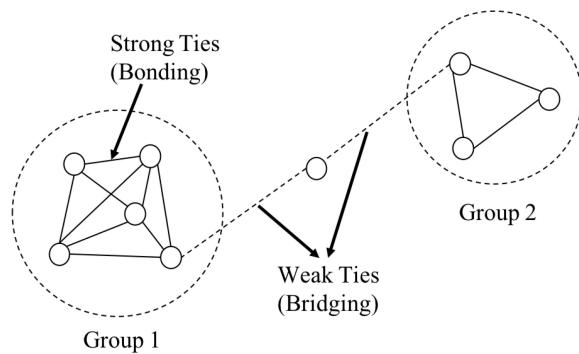


Fig. 2. Configuration of ties.

duals require both trust and reciprocity [27]. Ties in a social network are also described by the groups they connect [15]. *Bonding ties* connect homogeneous groups such as family and friends and are generally stronger in nature compared to bridging ties. *Bridging ties* connect more heterogeneous groups and are typically much weaker when compared to bonding ties [28]. Although often weak, bridging ties are viewed as crucial for individuals to move beyond their current social sphere and access new information or other resources that lie elsewhere in the network. Granovetter [27] explicitly considered weak ties as a kind of glue that holds together large networks of individuals, especially when those networks contain smaller, locally-strongly-tied sub-groups (as might exist in large-enrollment undergraduate classes). Weak ties can be cultivated in person or online via blogs and discussion forums; such online ‘virtual ties’ (while often anonymous) nonetheless expand access to resources within the network and represent an important form of bridging tie. Results presented later illustrate how the ABC structure encourages bridging ties to support student learning, while also providing opportunities for bridging ties to foster the creation of new social groups with shared norms and practices and, in turn, stronger bonding ties.

2.3.2 Dimensions of Social Capital

Social capital researchers identify three dimensions that characterize a given network of social relationships. The *structural* dimension includes the nature of ties among individuals, as well as the configuration and strength of ties. Configuration refers to the number of individuals in the social relationship and their position relative to each other, while the strength of those ties can be characterized as described above (directness and amount of trust/reciprocity). The *cognitive* dimension of social capital describes the resources within the network that help define shared representations among network members and interpretations of value and meaning among individuals. The cognitive dimension forms

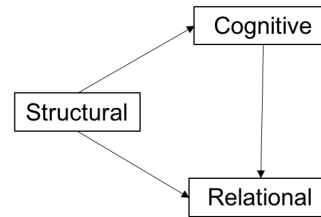


Fig. 3. Relationship among the various dimensions of social capital.

the basis for communication within the social group, by providing a vocabulary and set of common experiences from which to build relationships. Cognitive social capital also captures shared beliefs and values within the social network and codifies expected behaviors. The *relational* dimension sets expectations of trust, reciprocity, and identity of the social group and captures the overall quality and health of the relationships within the network. Social capital development across these three dimensions therefore depends upon the nature and strength of social ties, trust among the members in a network, and norms of collective action [29]. The cognitive, relational, and structural dimensions interact with each other, as the development of one dimension could contribute to the development of the other dimensions. For example, a high number of strong bonding ties (structural social capital) could improve the expectations of trustworthiness in the network and result in the enhancement of relational social capital.

2.3.3 Social capital development in higher education contexts

This paper focusses on the social capital generated among students through their social relationships and interaction with faculty and other students. However, for undergraduate students in a college or university, social capital is developed largely through their peer network and to a lesser extent through interactions with faculty and staff [12]. Students depend on the bonding ties they have with peers within their social groups to access academic or psychosocial support as they complete their course workload and navigate their overall experience. The mutual trust and reciprocity exhibited in such networks can be powerful and indeed crucial to the academic success of individuals and the social group as a whole [30]. Bridging ties are developed with more distant peers in their network, as well as with faculty and staff. Such ties are typically weak, sometimes tenuous, and often transactional in nature [31]. For example, students may engage faculty during their office hours with a question about course content, thereby using a bridging tie to access a very specific resource

(expert knowledge) from within their network. In general, and by mutual (implicit) agreement, both the student and faculty member might engage in this transaction with no serious expectation that the tie will become strong [32]. However, the hierarchy explicit in this faculty-student relationship (i.e., its structural configuration) reinforces shared values – both care about education and the student’s understanding of the course content – despite the comparatively weak nature of this bridging tie [33]. As such, both bonding and bridging ties have value to students in different circumstances and for different reasons. These different dimensions are explored in the context of this paper as we examine the students’ perceptions of their social resources inside and outside of the ABC classroom.

2.3.4 Comparison of social capital based on prior demographics of students

The Dynamics classroom in the Spring of 2016 comprised both male and female students who represented multiple racial/ethnic groups and included both domestic (USA) and international students. Although the availability of social capital has been found to facilitate the academic success of students in universities [34], it is important to note that social capital is not equally accessible or available to all members in a network [35]. Prior studies report that certain demographic characteristics such as ethnicity, gender, and international status result in a difference in the structural and relational social capital that is built and available among students in academic settings. For example, ethnic similarity among students in a group is considered to be a key characteristic for the development of social capital, as similarity in general inspires trust [36]. The high levels of trust that stem from ethnic similarity often lead to stronger bonding ties and as a result better use of the resources embedded in the social network [37]. Female students who tend to form small homogenous peer learning groups with other females are likely to have lower social capital and less access to resources [38]. International students were also observed to have lower social capital as they often struggle to become friends with domestic students and prefer to form smaller groups with individuals from the same nationality [39]. The stratification variables used in this study resulted in a sample that had achieved saturation in terms of students gender, ethnicity, and international status.

2.4 Social Capital in Active, Blended, and Collaborative Learning Environments

Active learning is defined as an instructional practice that encourages students to do some kind of motoric or physical action [40]. In the classroom, active learning is often accompanied by collabora-

tive approaches; instructors can provide students with collaborative learning opportunities by asking them to work with groups of two or more students towards a shared learning goal [41]. Collaborative learning is known to promote interpersonal interactions among individuals [42, 43], thereby strengthening ties within the social network. Through collaborative learning, students get an opportunity to use the knowledge resources of their peers in the social network as a learning resource [16]. Information sharing among peers could be a substitute for support that is not conveniently available from other sources, such as textbooks or instructors [44], especially in courses which are perceived to be difficult by students.

A course taught in a blended environment combines face-to-face and online instruction [45]. Prior studies have shown that blended course structures enable social capital development at least as well as more traditional course formats [46]. Blended learning can support synchronous and asynchronous interactions, both peer-to-peer and peer-to-instructor [47], which in turn provide more avenues to build network ties and develop social capital within the social network of the class. This suggests that students taking courses in a blended environment which provides multiple venues for interaction have better access to resources embedded in their social network via both bonding and bridging ties. The ABC environment described in this study provides such diverse venues as it integrated the three approaches of active, blended, and collaborative learning in a complementary way. We therefore study students’ experience in the course to examine whether and what dimensions of social capital are built in such a complex environment.

Interactions over a blog, which in this context is used to communicate with peers enrolled in the class about specific homework problems, are a form of collaboration through computers [48]. Through computer supported collaborative learning (CSCL), individuals communicate, share resources, engage in collaborative learning processes, and find and build groups and communities [41]. CSCL supports a social network by facilitating the development of mostly bridging ties among individuals in a larger community and, in the process, can broaden the size of the network. The active participation or collaboration of individuals through CSCL has been shown to broaden their social network and as a result increase their social capital [49]. However, collaboration via CSCL does not necessarily build strong ties, which require the development of trust, commitment, exchange of emotional support, and friendships [50]. The value of weak ties is in their provision of new information and access to networks that are heterogeneous in terms of their

demographic characteristics (Granovetter, 1977; Kraut, 1998; Wellman et al., 2001). Weak ties built over the internet have the potential to lead to a mixture of online and offline interactions [54], which can then lead to building stronger ties among individuals. The course blog therefore plays a special role in enabling a wider set of bridging ties among students and thus building structural social capital, and the results presented later describe this role in more detail.

3. Methods

3.1 Sampling and Data Collection

Interview data were collected during the spring semester of 2016, when four sections of the course were taught by four different instructors, each using the ABC paradigm. Total enrollment across the four sections was over 350 students. Participants were recruited for interviews based upon purposive stratified sampling by incoming GPA, international status, and section (instructor) as the stratification variables. Our stratification was informed by a quantitative study from the same research project that reported that these three parameters were significant predictors of a student's grade in the course [55]. Prior performance as measured by GPA could be a proxy for pre-existing social capital among students who already exercise their network in support of their academic success. International status introduces elements of acculturation to the process of building social ties, embedding trust in the network, and sharing resources [56]. Further, as noted above, students might form strong bonding ties with other international or racially/ethnically similar students, but this might also correspond to lower bridging ties [12]. Also, each instructor may have implemented the ABC classroom slightly differently, for instance by giving a different number of group quizzes throughout the semester.

Twenty-eight participants were recruited to participate in semi-structured interviews and were consented for this purpose. The participants included both male and female students and represented multiple ethnic groups. Distribution of the sample with respect to the stratification parameters is provided in Table 1. Each interview lasted about 30 minutes, and all were audio recorded and later transcribed using a third-party vendor. The interview protocol covered a wide range of topics includ-

ing student identity, institutional culture, the student experience in the ABC classroom, and the student perception of the various ABC learning resources.

3.2 Data Analysis

A thematic analysis approach was employed to analyze and interpret the coded interview data [57]. We took a social-constructivist approach to the thematic analysis [58], as we sought to theorize our findings based on the social structural conditions that enabled the students to develop the different types of social capital in the ABC learning environment. We conducted open-coding on all of the interview transcripts to generate a list of codes. These codes were then reviewed to look for overarching commonalities across the interview transcripts to generate the initial list of themes. The themes were then reviewed, redefined, and named appropriately to address the research question of the study. The three dimensions of social capital (structural, relational, and cognitive) were used as an analytical lens to organize and discuss the findings.

To establish the reliability of the results, two researchers simultaneously carried out coding of the student data. After coding the data individually, both the researchers met to discuss the results of each step of the coding process. For example, after the completion of the open-coding, both the researchers together reviewed the codes generated by them. During the review, they looked for commonalities and differences between the generated codes to check for the interrater reliability in the coded data [59]. The interrater reliability was established by calculating the ratio of number of agreements to the number of disagreements. Both the researchers conducted multiple iterations of open coding until a recommended level of reliability is established. Miles has recommended an interrater reliability of at least eighty percent [60] and we concluded the open coding process after establishing a reliability of eighty-four percent. The similar process was followed for each stage of the thematic analysis process to ensure the reliability of final themes that emerged from the data.

4. Results

There were eight dominant themes identified from the data. These describe key features of the student

Table 1. Distribution of sample as a result of purposive stratified sample

	Prior GPA		Nationality		Section			
	Low	High	Domestic	International	Inst 1	Inst 2	Inst 3	Inst 4
No. students	12	16	24	4	5	9	8	5

network in this ABC class. Each theme is presented along with relevant quotes from the participant interviews to provide additional context. Some of the quotes are bracketed to clarify the context or subject of discussion. In the Discussion section (Sec. 5), these themes are mapped onto the key dimensions of social capital. The themes were then synthesized into a clearer understanding of the ways in which this ABC learning environment does, and does not, promote the growth of social capital among students.

4.1 Theme 1 – ABC Pedagogies Provided Opportunities to Build New Ties

Students perceived the group quizzes facilitated in the classroom to have provided them with opportunities to develop potential bridging ties (among students who had not previously worked together) and reinforced pre-existing bonding ties (among students who worked with their social group). Several ABC instructors required the students to work with their peers through group quizzes during class sessions. During the group quizzes, students worked with and learned from their peers, and interview participants reported finding value in group work, as it extended their social network beyond their existing bonding ties. The instructors often asked students to form a new group for each quiz. As a result, the students built new bridging ties and solidified pre-existing bonding ties, both of which were perceived to be beneficial: *“Every week or so we break off into groups for about 20 minutes and then he [the instructor] encouraged us to meet new people . . . Usually we meet up with a group of three or more people and work through some problems together. I think it’s helpful”*.

While a few students acknowledged the in-class logistical challenges of forming new teams for each quiz, they believed that the exercise built a stronger community in the class: *“A couple of times, the instructor would make us move to other people during our quizzes. Logistically that was kind of a pain because we had so many [students] in the class, but I liked it because I was then working with someone else. I think that fostered a stronger community within the class”*. In this way, the instructor in the ABC environment intentionally created conditions under which new ties could be cultivated by students, thereby expanding their social network and increasing their social capital.

4.2 Theme 2 – Students Built ‘Virtual’ Social Capital via CSCL

The ABC environment fostered peer-to-peer communication via the course blog, providing another avenue for individual students to connect with peers and content-related information. The blog was

asynchronous, meaning students could post their queries and their peers could reply at their convenience, thus allowing out-of-class peer-to-peer collaboration. The same blog was available to all students enrolled in the course, across the four sections, and each student could use an alias to protect their anonymity if they desired. As such, blog participants were very likely conversing with students outside of their immediate friend group and collaborating with classmates they did not personally know in their communications. This provided students an additional avenue to increase the number of ties in their network outside of the classroom: *“Our professor has the blog for all of the four sections together. . . I think that promotes a collaborative learning environment”*.

Due to the anonymity of the users on the blog, it provided an avenue for students to give and receive help irrespective of their academic or cultural background. A student said: *“I feel like study groups would tend to form more among people who have about the same academic level or academic interest, but I feel like in the discussion forum [blog], that’s not necessarily true since you don’t have to be in person”*. The weak ‘virtual’ ties built through the blog, though anonymous, increase the access to social capital available in the network, as students are able to access and utilize the resources embedded in the tie. It is important to note the discussion threads on the blog were organized specifically for homework problems and students could therefore access targeted help-seeking resources that were available through these virtual ties. Through the blog, students were able to expand their number of ties with individuals across the different sections, regardless of their social identity and demographic factors such as gender, ethnicity, race, and international status.

4.3 Theme 3 – Sharing Resources Encouraged and Supported Academic Help-Seeking

The varied help-seeking behaviors exhibited in the community illustrated the nature of students’ engagement and provided insights into how collaborative learning contributed to the development of social capital. Encouraging students to work in groups provided them an avenue for immediate feedback from their peers on the concepts and problems taught in class. One student said, *“Some of the quizzes we have are collaborative . . . That’s really cool because a lot of the conceptual components of the course are really confusing and easy to mix up... so it’s cool to be able to work on that and be able to immediately get feedback”*. Another student reiterated: *“It was good to discuss and then kind of talk, because a lot of times you’re trying to just think out a problem, you make steps that are not valid and if*

you're talking about it with somebody, you don't make those incorrect steps". Students reported this approach to be helpful as they could receive personalized support from their peers, an opportunity which is not often possible in large classrooms [58].

Interviewees reported engaging with their peers in the classroom even when they were not necessarily working on a quiz: *"Even if it's not during a quiz, if there's an example that the professor is leading that isn't clear to any one of us, we'll have a quick whisper, where did he get that from? Usually we are able to help each other out and figure out exactly what the professor is doing just for ourselves, instead of having to ask the professor every time."* Students therefore continued to seek help from peers through alternate avenues that were not necessarily facilitated by the instructor. The help-seeking behavior extended outside of the class as students worked on homework problems: *"Probably a couple hours a week I'll go sit somewhere with some of my friends who have the same homework and we'll work on it together... Even in the last homework you did, if you thought you did it all right, and you then go do it with some other people, you'll realize that you had done it in a wrong way or forgot a step"*. Interviewees mentioned using their peers to seek help and provide information about efficient problem-solving strategies: *"I would use my peers by asking questions about certain parts on how to do certain little tricks in each problem [homework], and it was nice"*. Students were expected to submit homework problems thrice a week, and the frequency of help-seeking could therefore be high outside of the class. Students reported that the ties developed and resources shared through the members in the network had a positive impact on their learning: *"This class, I feel more than any other class, I've had to ask for help and work with people which then made me learn everything better"*.

4.4 Theme 4 – Students Consistently Participated in the Community

Dynamics is considered by subject matter experts to be a challenging gateway course in the university engineering curriculum [62], and one clear emergent theme was the students' perceptions of peer-to-peer collaboration as a constant, necessary strategy. ABC instructors frequently fostered this collaborative culture by encouraging students to participate in group discussions in the classroom; one student said: *"I think because of the way they [the instructor] taught it, and the way they did group quizzes, they were encouraging us to take advantage of our peers"*. The same was reiterated by numerous other students: *"The classroom is very collaborative... if the professor isn't like teaching us something directly, you're always working in a group of two or three no*

matter what". Students described collaborative learning behaviors that were consistent outside the class as students solved the frequent homeworks: *"I use my peers almost every day of the week for homework, studying, clarification on concepts, and they were my most useful resource"*. Students' responses about frequent, active collaboration with other students in their social network is an indicator of their commitment to engage in the community and a clear illustration of the way in which they engaged social capital being developed in the network.

4.5 Theme 5 – Interactions among Students were typically Reciprocal

Students in the Dynamics course reported that their peers often showed reciprocity during collaboration (one facet of strong, bonding ties [63]), as they provided and sought help. This was evident as one student said: *"I think it's sort of a, treat others as you'd like to be treated, kind of thing. You know, if you have something to offer, it's worth offering it to others that need it so that maybe one day they'll help you in return"*. This reciprocal approach to resource sharing within the social network was a particularly strong theme when students described working on their homework in person outside of the classroom. As one student said: *"I thought this [peer interaction] was especially helpful because we could teach our peers when we knew what was wrong and we could learn from our peers when we didn't know what was wrong"*.

Students used similar language about reciprocity both to describe the weak ties inherent to the blog and for strong ties associated with face-to-face collaboration. One student described their approach to completing homework assignments, including their contributions to the blog: *"I'll try the [homework] problem. If I can't get through it on my own, then I'll check the various blog comments that people have left, and then pitch in if I can"*. This reciprocity among individuals is often essential to leverage the resources available in the social network, as it strengthens the ties in the network by reinforcing existing norms and trust. As observed from the student quotes that characterize this theme, students mentioned that the reciprocity among their peers motivated them to proactively collaborate and offer support when needed. This motivation was attributed to the students' confidence and trust that their peers would help them in return when necessary.

4.6 Theme 6 – Students were comfortable working with Peers

A clear theme that emerged was the concept of 'comfort' with social interactions in multiple spaces in the ABC environment. Participants

reported high comfort when working with their peers in person, especially when working with peers with whom they shared bonding ties. They frequently described study groups among friends in which they worked together on homework assignments: *“It’s good to be able to work in study groups and do our homework. Since I know them and I’m comfortable with them, I can ask questions and I don’t feel bad or embarrassed”*. Students reported being comfortable collaborating with peers whom they already knew. While the study group scenario is common and aligned with the overall departmental culture, this ABC environment reinforced it and provided students with opportunities to collaborate with new students while working on group quizzes in the classroom. The collaborative element of the ABC environment fostered the feeling of comfort among students without feeling vulnerable while engaging in group discussions. One student said, *“I think it’s just because [working with peers] people are more willing to talk about it and want to know, ‘Oh, hey, I’m doing this. Is this what everyone else is doing?’ to see if it’s in line. It’s more comfortable to work in that kind of group setting. It makes you feel more confident about what you’re doing”*. The feeling of comfort among students resonates with the philosophy of the learning environment where peer collaboration is an established norm in the network and is actively encouraged by the instructors.

4.7 Theme 7 – Students Perceived the Social Networks and Collaborative Spaces to be Largely Trustworthy

When members in a network build strong ties with high levels of trust, they are more inclined to exchange knowledge [64]. As such, trust mediates the reciprocity theme described above; with a high level of trust, an individual is more willing to access and contribute to the social capital in the network. However, trust to a large extent serves as a prerequisite for acquisition of social capital, especially through bonding ties. The trust in a social network is built through the repetitive, positive, and meaningful exchange of social capital among students. This is explicitly fostered in the ABC environment by encouraging students to repeatedly work on group quizzes and interact with each other through the course blog. However, as students had limited information about the identities of people with whom they built bridging ties on the blog, they perceived the help they received in-person to be more trustworthy: *“I would say the level of trust is probably higher [as compared to the blog] in my opinion, just because you know for sure who’s giving you that feedback. I know if my friend who is really doing well in this class said, here’s how you do it, I’m*

definitely going to trust what they say”. This is a clear illustration of participants privileging trusted bonding ties over bridging ties when possible, which is consistent with prior literature [31].

Nonetheless, the ABC structure of *Freeform* was designed to promote trust within the community, and students as a result could more easily build crucial bridging ties with other students beyond their usual social network. Participants described receiving and/or providing assistance from/to individuals outside their traditional network, who were not necessarily their friends, both in person and on the blog: *“I think other students are a really good resource and it’s more than just your friends, it’s somebody that you probably never would have gotten help from”*.

4.8 Theme 8 – Students Experienced Behaviors that Hindered Social Capital Development

Our prior work confirmed that students in this ABC environment use course resources in combination with each other [65]. As such, students have opportunities to build different ties of different strengths through their use of course resources. The choice to not use a specific resource: (i) hinders that resource’s ability to help the student develop certain kinds of ties, but (ii) may direct the student to other resources that have their own affordances for tie building. Several participants mentioned their unhelpful experiences with the course blog; for example: *“I would definitely say that I use that resource [the blog] the least because there’s various information. It’s pretty common for a student to say something and then another student to be like, ‘Well, I got this’ and another student to be like, ‘Well, I got this’. Now you have three options. You came to the blog because you were confused and now you have three options. It doesn’t help me”*. This participant therefore did not experience the bridging-tie-building interactions on the course blog, but perhaps they used other resources, such as in-person peers, to support their learning and build a different kind of social tie. Another participant remarked: *“I thought the blog was not as helpful. I think it could be better if the professors went on and answered some of the student’s questions rather than just the students communicating”*. In a similar way, this participant opted out of blog usage, therefore limiting construction of their bridging ties, and they suggested a more trustworthy solution (see also Sec. 4.7) that would have promoted their use of the blog. Participant statements like these emphasize how structural features of specific ABC resources (here, blog content) drove specific behaviors (not using the blog), which in turn hindered the development of blog-based bridging ties while potentially encouraging development of other ties via the use of other course resources.

5. Discussion

In this section, we map the emergent themes onto the dimensions of social capital and expand upon the implications of each (Table 2). The first three section headings correspond to the three dimensions of social capital, and interview responses and themes from Section 4 are interpreted and synthesized within the context of these dimensions.

5.1 Structural Social Capital

Structural social capital encompasses both the configuration and strength of ties among individuals in the network, and it influences access to the resources available within the network. The structural dimension of social capital looks at the overall pattern of connections among the members, i.e., with whom and how they establish ties [26]. Students cited formation of bridging and strengthening of bonding ties as key elements of their experience in the ABC environment. We limit our discussion to the social capital that was built among the students through the course and acknowledge that the students could have additionally interacted with other individuals (students not in the course, faculty, and teaching assistants), which might also contribute to the development of their social capital. The students studying in the ABC learning environment reported opportunities to strengthen their pre-existing bonding ties through collaboration with peers in-person, both inside and outside of the classroom. The group quizzes provided in the classroom helped the students to establish a sense of trust and comfort in peer learning, thereby strengthening the student-student ties. Students also built bridging ties in the classroom when the instructor encouraged them to collaborate with other students who they had not worked with before. While the collaboration inside of the classroom was often facilitated by the instruc-

tor, the face-to-face collaboration outside of the classroom aligned with the culture in the school in general and the collaborative philosophy of the ABC environment. The strong bonding ties forged or strengthened through the ABC environment provided students with greater access to the resources embedded in the network.

Students built bridging ties with peers outside the classroom through computer supported collaborative learning over the blog. The blog provided students with an opportunity to interact with individuals from different backgrounds, which contributed to the structural social capital of the individual as they were now connected to more members in the network [66]. This increased structural social capital contributed to the bridging ties developed with potentially heterogeneous peer groups, which (in a typical classroom) do not occur regularly due to the greater effort needed to forge the interactions [25]. This ABC classroom provided multiple structured ways to engage in bridging interactions via in-class collaborative quizzes and the out-of-class asynchronous blog communications. While transactional in nature, the bridging ‘virtual’ interactions supported by the course blog nonetheless played an important role in the participants accessing help from their peers. This is true even for students who were not actively engaged in the online discussion, but who could nonetheless read the discussion threads and access the academic help therein. The development of bridging and bonding ties and the utilization of the structural social capital built through these ties are known to have a positive impact on students’ performance [12].

5.2 Cognitive Social Capital

The participants’ responses coalesced around the theme of peer collaboration providing an avenue for immediate feedback on the concepts and problems

Table 2. Mapping of emergent themes onto the dimensions of social capital

Theme (Sec. 4)	Social Capital Dimension (Sec. 5)	Notes
4.1 ABC pedagogies provided opportunities to build new ties. 4.2 Students built ‘virtual’ social capital via CSCL.	Structural Structural	Both bonding and bridging ties add value, with the strength of ties mediated by relational factors such as trust.
4.3 Sharing resources encouraged and supported academic help-seeking.	Cognitive	Help-seeking behaviors are shaped by the ties being exercised (bridging or bonding).
4.4 Students consistently participated in the community. 4.5 Interactions among students were typically reciprocal. 4.6 Students were comfortable working with peers. 4.7 Students perceived the social networks and collaborative spaces to be largely trustworthy.	Relational Relational Relational Relational	Both structural and cognitive dimensions are underpinned by positive relationship dynamics among students who demonstrate both comfort and reciprocity.
4.8 Students experienced behaviors that hindered social capital development.	Any/all	Student choices about resource usage may hinder their development of specific kinds of social capital.

being examined in the class. Participants noted the importance of encouraging and facilitating peer collaboration which in the last several years has become an accepted norm in this ABC environment. Peer collaboration was necessary to overcome some of complex academic challenges that students experience while navigating through courses in the sophomore or junior year of their undergraduate program. These instances in which students communicated a shared understanding of the different learning strategies to succeed in the course contributed to the development of the cognitive dimension of social capital in the network. The development of cognitive social capital provided the students access to information through other individuals in the network, which in turn reinforced the norms of communication and sharing within the group. The ABC learning environment reinforced the extant undergraduate culture by providing the students with multiple structured avenues to collaborate both inside and outside of the classroom. These frequent, content-oriented peer-to-peer interactions among students contributed to their overall sense of engagement (both academically and socially), the benefits of which have been well documented [7]. Research indicates that the utilization of cognitive social capital while studying promotes deeper learning, as the students get a chance to explain the course concepts to each other and clarify misconceptions in the process [67].

5.3 Relational Social Capital

The relational dimension of social capital describes interactions among individuals and the shared norms developed in the process. Some of the key factors include the amount of time spent, expectations, and trustworthiness of the relationships [26]. The interaction of students with their peers inside and outside of the classroom, and over the blog, was an indicator of their high level of commitment and willingness to participate in the community. The themes emergent from the data showed that the students felt comfortable, perceived relationships (via bonding ties) to be trustworthy, and often reciprocated while working with their peers. The reciprocal nature of the interaction increases the students' perceived value of the social capital available in the network, and as a result improved trustworthiness among the students, which could contribute to the development of stronger ties in the network [31].

These shared norms established in the network mediate the development of stronger bonding ties with peers, an essential element of active and effective usage of the social capital in a community [68]. Moreover, the presence of relational social capital supports key academic goals. Prior studies

reported that the trust and feelings of connectedness among students in a class had a positive correlation with the level of learning [69]. Coleman reported that the high level of relational social capital among the students was correlated to higher academic success and a lower drop-out rate of students [20, 70]. The ABC environment of *Freeform* therefore reinforced positive behaviors by enabling the formation of relational social capital and allowing the frequent use of social capital throughout the student network. While anonymous, interactions on the blog did support a sense of comfort and reciprocity among participants and provided access to help resources for homework problems. While we observed no evidence of 'virtual' bridging ties building into bonding ties in person, these online weak ties nonetheless played Granovetter's role of social 'glue' within the broader network by enabling information sharing and collaboration among students [52].

5.4 Interaction between Cognitive, Relational, and Structural Social Capital

The interplay among the dimensions of social capital was also evident in the themes identified here. The strength of the ties among individuals (a structural feature) depended on the trustworthiness and reciprocity in the relationship [27]. The stronger the ties among individuals, the higher the structural social capital, and the higher the chances for resource sharing and subsequent impact on individual and social group outcomes [25]. Trustworthiness among members in the network (relational social capital) was not only a prerequisite for stronger ties but also an outcome of positive resource sharing experiences. Anonymous interactions over the blog built weaker, bridging ties among students that could nonetheless strengthen the overall social network by connecting more strongly-tied sub-groups [27].

From a research-to-practice perspective, the relational social capital theme of trustworthiness directly inspired a course structural change. Participants described instances in which information provided on the blog was perceived to be unhelpful because multiple solution pathways were suggested for a single homework problem. Some participants found this confusing, because they were unsure how to value the relative merit of the different pathways (because, in their estimation, they were unsure how to evaluate the trustworthiness of the individual providing the guidance). The instructors included a new feature on the blog that allowed users to 'upvote' comments they perceived to be useful, thereby indicating a community-established trustworthiness measure for each comment. This feature was implemented to enhance the trustworthiness of

blog communication and promote the continued development and strengthening of bridging ties.

5.5 Limitations and Future Scope of Study

One limitation to our analysis is the unavailability of international students' country of origin. Our institution records students using a binary variable – a student is 'international' or not – without tabulating the student's actual country of origin. As a result, we can essentially no conclusions about alignment between a participant's country of origin and its prevailing norms about collaboration and social capital, as compared to their behaviors related to social capital development in this ABC classroom. Information about international students' nationality in addition to their race/ethnicity would have allowed us to conduct a deeper investigation on participants' behaviors in the course. For future studies, we propose explicit data collection around participants' home countries and their experiences of social capital in prior educational settings. Their interview responses could be compared and contrasted based on their nationality and race/ethnicity. With the additional sample information, we anticipate deeper insights into development of social capital as the nature of interactions and help-seeking behaviors would vary among homogenous and heterogenous (in terms of nationality, race/ethnicity) student groups. This additional layer of analysis could help instructors and course designers develop more tailored resources and course platforms that would maximize the development of social capital and thus help students succeed in engineering courses.

Based upon the outcomes of this study, we envision future studies using refined protocols that probe social capital development more deeply and with a larger sample of students. The protocols can be refined in at least two dimensions. First, future studies should collect more factual data about participant relationships with peers, both in person and online. This data could be collected through voluntary disclosure by each participant, or through more detailed data collection and analytics on the use of online resources – for instance, tracking participants in discussion threads on the course blog. A more detailed understanding of the social network of each participant, including strength and configuration of their relationships, would allow for substantially more depth in a social capital analysis.

Second, the interview protocol should be updated to probe in greater depth participant perceptions of the trade-offs of using specific resources as they affect social capital development. Taken together, these updates to the study will enable much deeper insights about student resources usage and the consequences on social capital development.

6. Conclusions

This paper examined how a multi-faceted ABC learning environment for a core STEM subject contributed to the development of different dimensions of social capital among students. Key themes that emerged from student interviews included interactions over the blog widening their peer network through bridging ties. Although these bridging ties were weak, they were nonetheless useful for accessing new information available in their broader social network. However, students perceived the growth of strong, bonding ties with their peers when they worked with peers in-person, inside and outside of the classroom. We identified themes in the data reporting that students viewed their peers as valuable resources and showed reciprocity, comfort, and trust as characteristics of the class social network while working with each other. The collaborative component of the classroom contributed to the development of strong ties among the students, which resulted in a high level of commitment to their community in the course. The virtual bridging ties built over the course blog were however transactional in nature and limited the potential of converting them to a bonding tie. Instructors teaching undergraduate STEM courses could use such ABC learning environments to help students succeed academically by providing multiple avenues for students to effectively develop and access social capital. This sense of community developed during the sophomore year has the potential to continue assisting students as they navigate through the remainder of their academic program.

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References

1. V. Tinto, Research and Practice of Student Retention: What next?, *J. Coll. Stud. Retent.*, **8**(1), pp. 1–19, 2007.
2. M. J. Graham, J. Frederick, A. Byars-Winston, A.-B. Hunter and J. Handelsman, Increasing Persistence of College Students in STEM, *Science*, **341**(6153), pp. 1455–1456, Sep. 2013.
3. M. Dagley, M. Georgiopoulos, A. Reece and C. Young, Increasing Retention and Graduation Rates Through a STEM Learning Community, *J. Coll. Stud. Retent. Res. Theory Pract.*, **18**(2), pp. 167–182, Aug. 2016.

4. G. Crosling, M. Heagney and L. Thomas, Improving Student Retention in Higher Education: Improving Teaching and Learning, *Aust. Univ. Rev.*, **51**(2), pp. 9–18, 2009.
5. L. Grebennikov and M. Shah, Investigating Attrition Trends in Order to Improve Student Retention, *Qual. Assur. Educ.*, **20**(3), pp. 223–236, 2012.
6. V. Tinto, Dropout from Higher Education: A Theoretical Synthesis of Recent Research, *Rev. Educ. Res.*, **45**(1), pp. 89–125, 1975.
7. V. Tinto, *Leaving College: Rethinking the Causes and Cures of Student Attrition*. University of Chicago Press, 5801 S, 1987.
8. L. Willcoxson, J. Cotter and S. Joy, Beyond the first-year experience: the impact on attrition of student experiences throughout undergraduate degree studies in six diverse universities, *Stud. High. Educ.*, **36**(3), pp. 331–352, 2011.
9. S. S. Graunke and S. A. Woosley, An Exploration of the Factors That Affect the Academic Success of College Sophomores, *Coll. Stud. J.*, **39**(2), pp. 367–376, Jun. 2005.
10. B. M. Woodside, E. H. Wong and D. J. Wiest, The effect of student-faculty interaction on college students' academic achievement and self concept, *Education*, **119**(4), pp. 730–733, 1999.
11. E. N. Eren Şişman, C. Çigdemoglu and Ö. Geban, Investigation of the Effect of Peer-Led Team Learning Model on University Students' Exam Achievement in General Chemistry, *Akran-Liderliğinde Takım Öğrenmesi Model. Üniversite Öğrencilerinin Genel Kim. Sınav Başarısı Üzerindeki Etkisinin İncelenmesi*, **7**(2), pp. 636–664, 2018.
12. L. Daza, The role of social capital in students' perceptions of progress in higher education, *Educ. Res. Eval.*, **22**(1–2), pp. 65–85, Feb. 2016.
13. J. F. Rhoads, E. Nauman, B. M. Holloway and C. M. Krougrill, The Purdue Mechanics Freeform Classroom: A New Approach to Engineering Mechanics Education, in *Proceedings of the 121st ASEE Annual Conference and Exposition*, 2014, p. Paper ID #9006.
14. J. DeBoer, N. Stites, E. Berger, J. Rhoads, C. Krougrill, D. Nelson, C. Zywicki and D. Evenhouse, Work in Progress: Rigorously Assessing the Anecdotal Evidence of Increased Student Persistence in an Active, Blended, and Collaborative Mechanical Engineering Environment, *Proc. 123rd ASEE Annual Conference and Exposition*, 2016.
15. R. D. Putnam, Bowling Alone: America's Declining Social Capital, *J. Democr.*, **6**(1), pp. 65–78, 1995.
16. S. Brown, D. Street and J. P. Martin, Engineering Student Social Capital in an Interactive Learning Environment, *Int. J. Eng. Educ.*, **30**(4), pp. 813–821, 2014.
17. W. D. Oberman and E. T. Hill, Discovering the Paths to Building Social Capital: Complex Campus and Community Linkages in Continuing Higher Education, *J. Contin. High. Educ.*, **56**(3), pp. 2–10, 2008.
18. E. T. Pascarella and P. T. Terenzini, *How college affects students*, 1991. Jossey-Bass San Francisco.
19. P. Temple, Creating social capital: The impact of international programmes on Polish and Romanian higher education, *Tert. Educ. Manag.*, **12**(1), pp. 1–20, 2006.
20. J. D. Teachman, K. Paasch and K. Carver, Social capital and dropping out of school early, *J. Marriage Fam. Minneap.*, **58**(3), pp. 773–783, 1996.
21. S. Huang and N. Fang, Predicting student academic performance in an engineering dynamics course: A comparison of four types of predictive mathematical models, *Comput. Educ.*, **61**, pp. 133–145, Feb. 2013.
22. E. K. Briody, E. J. Berger, E. Wirtz, A. Ramos, G. Guruprasad and E. F. Morrison, Ritual as work strategy: A window into organizational culture, *Hum. Organ.*, **77**(3), 2018.
23. E. Wirtz, A. Dunford, E. J. Berger, E. K. Briody, G. Guruprasad and R. Senkpeil, Resource Usage and Usefulness: Academic Help-Seeking Behaviours of Undergraduate Engineering Students, *Australas. J. Eng. Educ.*, vol. in review, 2018.
24. E. K. Briody, E. Wirtz, A. Goldenstein and E. Berger, Breaking the Tyranny of Office Hours: Overcoming Professor Avoidance, *Eur. J. Eng. Educ.*, **44**(5), pp. 666–687 2019.
25. N. Lin, *Social capital: A theory of social structure and action*, Cambridge University Press, 2002.
26. J. Nahapiet and S. Ghoshal, Social Capital, Intellectual Capital, and the Organizational Advantage, *Acad. Manage. Rev.*, **23**(2), pp. 242–266, 1998.
27. M. S. Granovetter, The Strength of Weak Ties, in *Social Networks*, Elsevier, pp. 347–367, 1977.
28. K. Paton, Conceptualising 'Choice': A review of the theoretical literature, *Sch. Educ. Univ. Southampt.*, 2007.
29. A. Q. Liu and T. Besser, Social Capital and Participation in Community Improvement Activities by Elderly Residents in Small Towns and Rural Communities, *Rural Sociol.*, **68**(3), pp. 343–365, Sep. 2003.
30. E. K. Briody, E. J. Berger, E. Wirtz, A. Ramos, G. Guruprasad and E. F. Morrison, Ritual as Work Strategy: A Window into Organizational Culture, *Hum. Organ.*, vol. In Press, 2018.
31. C. Fuller, Social Capital and the role of trust in aspirations for higher education, *Educ. Rev.*, **66**(2), pp. 131–147, 2014.
32. M. A. Jaasma and R. J. Koper, The relationship of student-faculty out-of-class communication to instructor immediacy and trust and to student motivation, *Commun. Educ.*, **48**(1), pp. 41–47, 1999.
33. S. L. Dika, Relations With Faculty as Social Capital for College Students: Evidence From Puerto Rico, *J. Coll. Stud. Dev.*, **53**(4), pp. 596–610, 2012.
34. E. Villar and P. Albertin, 'It is who knows you'. The positions of university students regarding intentional investment in social capital, *Stud. High. Educ.*, **35**(2), pp. 137–154, 2010.
35. N. Lin, Inequality in social capital, *Contemp. Sociol.*, **29**(6), pp. 785–795, 2000.
36. S. M. Gaddis, What's in a Relationship? An Examination of Social Capital, Race and Class in Mentoring Relationships, *Soc. Forces*, **90**(4), pp. 1237–1269, 2012.
37. I. Light and E. Bonacich, *Immigrant Entrepreneurs: Koreans in Los Angeles*, University of California Press, 1988.
38. J. P. Martin, S. Brown, M. K. Miller and S. K. Stefl, Characterizing Engineering Student Social Capital in Relation to Demographics, *Int. J. Eng. Educ.*, **31**(4), pp. 914–926, 2015.
39. C.-M. Zhao, G. D. Kuh and R. M. Carini, A Comparison of International Student and American Student Engagement in Effective Educational Practices, *J. High. Educ.*, **76**(2), pp. 209–231, 2005.
40. M. T. H. Chi and R. Wylie, The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes, *Educ. Psychol.*, **49**(4), pp. 219–243, Oct. 2014.
41. H. Jeong and C. E. Hmelo-Silver, Seven Affordances of Computer-Supported Collaborative Learning: How to Support Collaborative Learning? How Can Technologies Help?, *Educ. Psychol.*, **51**(2), pp. 247–265, 2016.

42. D. W. Johnson, R. T. Johnson and K. A. Smith, *Active Learning: Cooperation in the College Classroom*, Interaction Book Company, Edina, MN, 1998.
43. L. Springer, M. E. Stanne, and S. S. Donovan, Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis, *Rev. Educ. Res.*, **69**(1), pp. 21–51, 1999.
44. S. Brown, L. Flick and T. Fiez, An Investigation of the Presence and Development of Social Capital in an Electrical Engineering Laboratory, *J. Eng. Educ.*, **98**(1), pp. 93–102, 2013.
45. B. Means, Y. Toyama, R. Murphy, M. Bakia and K. Jones, Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies, *US Dep. Educ.*, 2009.
46. C. Carceller, S. Dawson and L. Lockyer, Social capital from online discussion forums: Differences between online and blended modes of delivery, *Australas. J. Educ. Technol.*, **31**(2), pp. 150–163, 2015.
47. S. A. Gyamfi and P. O. Gyaase, Students' Perception of Blended Learning Environment: A Case Study of the University of Education, Winneba, Kumasi-Campus, Ghana, *Int. J. Educ. Dev. Using Inf. Commun. Technol.*, **11**(1), pp. 80–100, 2015.
48. E. Lehtinen, K. Hakkarainen, L. Lipponen, M. Rahikainen and H. Muukkonen, Computer supported collaborative learning: A review, *JHGI Giesbers Rep. Educ.*, **10**, p. 1999, 1999.
49. H. Cho, G. Gay, B. Davidson and A. Ingrassia, Social networks, communication styles, and learning performance in a CSCL community, *Comput. Educ.*, **49**(2), pp. 309–329, 2007.
50. B. Wellman, A. Q. Haase, J. Witte and K. Hampton, Does the Internet Increase, Decrease, or Supplement Social Capital?: Social Networks, Participation, and Community Commitment, *Am. Behav. Sci.*, **45**(3), pp. 436–455, 2001.
51. R. Kraut, Internet paradox: A social technology that reduces social involvement and psychological well-being?, *Am. Psychol.*, **53**(9), pp. 1017–1032, 1998.
52. M. S. Granovetter, The Strength of Weak Ties, in *Social Networks*, Elsevier, pp. 347–367, 1977.
53. B. Wellman, A. Q. Haase, J. Witte and K. Hampton, Does the Internet Increase, Decrease, or Supplement Social Capital?: Social Networks, Participation, and Community Commitment, *Am. Behav. Sci.*, **45**(3), pp. 436–455, 2001.
54. H. Rheingold, *The virtual community: homesteading on the electronic frontier*, MIT Press, Cambridge, MA, 2000.
55. N. A. Stites, C. Zywicki, E. Berger, C. Krousegrill, J. F. Rhoads and J. DeBoer, The impact of instructor experience on student success for a blended, undergraduate engineering class, in *AERA Annual Meeting, San Antonio, TX*, 2017.
56. R. A. Smith and N. G. Khawaja, A review of the acculturation experiences of international students, *Int. J. Intercult. Relat.*, **35**(6), pp. 699–713, 2011.
57. V. Braun and V. Clarke, Using thematic analysis in psychology, *Qual. Res. Psychol.*, **3**(2), pp. 77–101, 2006.
58. R. E. Boyatzis, *Transforming qualitative information: thematic analysis and code development*, Thousand Oaks, CA: Sage Publications, 1998.
59. Beth Harry, K. M. Sturges and J. K. Klingner, Mapping the Process: An Exemplar of Process and Challenge in Grounded Theory Analysis, *Educ. Res.*, **34**(2), pp. 3–13, Mar. 2005.
60. M. B. Miles, *Qualitative data analysis: an expanded sourcebook*, 2nd ed. Sage Publications, Thousand Oaks CA, 1994.
61. J. T. Boyle and D. J. Nicol, Using classroom communication systems to support interaction and discussion in large class settings, *J. Res. Learn. Technol.*, **11**(3), pp. 43–57, 2003.
62. M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra and R. A. Layton, Persistence, Engagement, and Migration in Engineering Programs, *J. Eng. Educ.*, **97**(3), pp. 259–278, 2008.
63. G. Arriaza and C. Rocha, Growing Social Capital in the Classroom, *Issues Teach. Educ.*, **25**(1), pp. 59–71, 2016.
64. J. S. Coleman, *Foundations of Social Theory*, Harvard University Press, Cambridge, MA, 1990.
65. N. A. Stites, E. Berger, J. DeBoer and J. F. Rhoads, A Cluster-Based Approach to Understanding Students' Resource-Usage Patterns in an Active, Blended, and Collaborative Learning Environment, *Int. J. Eng. Educ.*, **35**(6), pp. 1738–1757, 2019.
66. B. Wellman and K. Frank, Network capital in a multilevel world: Getting support from personal communities, *Soc. Cap. Theory Res.*, pp. 233–273, 2001.
67. M. D. Svinicki, *Learning and motivation in the post-secondary classroom*. Anker Publishing Company, Bolton, MA, 2004.
68. D. McAdam, *Political process and the development of Black insurgency, 1930–1970*, 2nd ed. Chicago, IL: University of Chicago Press, 1999.
69. A. P. Rovai, Sense of community, perceived cognitive learning, and persistence in asynchronous learning networks, *Internet High. Educ.*, **5**(4), pp. 319–332, 2002.
70. J. S. Coleman, Social Capital in the Creation of Human Capital, *Am. J. Sociol.*, **94**, pp. S95–S120, 1988.

Rohit Kandakatla, PhD is currently serving as the Director for Strategy, Operations, and Human Resource Development at KG Reddy College of Engineering and Technology. He also has an adjunct faculty appointment with the Center for Engineering Education Research at KLE Technological University. He completed his PhD in Engineering Education from Purdue University, Masters in Embedded Systems from Jawaharlal Nehru Technological University Hyderabad, Bachelor of Engineering in Electronics and Communication from Manipal Institute of Technology. His research interests include education policy, faculty development, understanding organizational development in higher education, and integration of technology and entrepreneurship in engineering education.

Edward Berger, PhD is a Professor of Engineering Education and Mechanical Engineering at Purdue University, joining Purdue in August 2014. He has been teaching mechanics for nearly 20 years and has worked extensively on the integration and assessment of specific technology interventions in mechanics classes. He was one of the co-leaders in 2013–2014 of the ASEE Virtual Community of Practice (VCP) for mechanics educators across the country. His current research focuses on student problem-solving processes and use of worked examples, change models and evidence-based teaching practices in engineering curricula, and the role of non-cognitive and affective factors in student academic outcomes and overall success.

Jeffrey F. Rhoads, PhD is a Professor in the School of Mechanical Engineering at Purdue University and is affiliated with both the Birck Nanotechnology Center and Ray W. Herrick Laboratories at the same institution. He received his BS, MS, and Ph.D. degrees, each in mechanical engineering, from Michigan State University in 2002, 2004, and 2007, respectively. Dr. Rhoads' current research interests include the predictive design, analysis, and implementation of resonant micro/nanoelectromechanical systems (MEMS/NEMS) for use in chemical and biological sensing, electromechanical signal processing, and computing; the dynamics of parametrically-excited systems and coupled oscillators; the thermo mechanics of energetic materials; additive manufacturing; and mechanics education.

Jennifer DeBoer, PhD is currently an Assistant Professor of Engineering Education at Purdue University. Her research focuses on international education systems, individual and social development, technology use and STEM learning, and educational environments for diverse learners. Dr. DeBoer obtained her PhD in international education policy studies from Vanderbilt University in 2012 and two bachelor's degrees in mechanical engineering and foreign languages from MIT. Before joining the faculty of engineering education at Purdue in 2014, she served as a postdoctoral associate for education research at MIT.