Impact of Instructor Intervention on the Conceptual Understanding of Undergraduate Engineering Students Working in a Group

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Abstract: This preliminary study examines interaction patterns between instructors and students and how the interactions impact students' conceptual understanding. Video data was drawn from four discussion sections in a required undergraduate engineering course involving six instructors. Emergent coding schemes were developed and were used to analyze how different instructors intervened in groups of students during different scenarios. Confirmatory factor analysis (CFA) was performed to understand the main contributors of interaction that led to high conceptual understanding talk. The study suggests that the instructor's observation of students before intervention does not significantly affect their interaction with students or their conceptual understanding discourse. Non-IRE (Initiate-Response-Evaluate) discourse patterns and scaffolding for problem solving were primary estimators of instructor-student interaction quality. There was a significant effect of instructor-student interaction on their conceptual understanding discourse.

Introduction

With the increase of collaborative learning across STEM fields (Wieman et al., 2010), it is especially important for us to understand how best to support learning in these contexts. Until recently, the role of the instructor in supporting groups had received little attention in the literature, yet is critical for successful groups (Kaendler et al., 2015). Student discourse plays a vital role in their conceptual understanding (Decristan et al., 2015). This preliminary study examines interaction patterns between instructors and students and how the interactions impact the conceptual understanding of the students by analyzing the student discourse during instructor intervention.

Theoretical Framework

Collaborative learning builds on constructivist learning theory, specifically social constructivism. Research on collaborative learning has shown that when groups of students construct knowledge through iterative social interactions, it can lead to higher levels of understanding (Roschelle, 1992). Collaborative learning is a joint meaning-making process between members of a group. Students need to be supported during group work to effectively collaborate in order to engage in effective processes (Kreijns et al., 2003; Miyake et al., 2019).

Well-designed collaborative tasks are required to support student collaboration. Problem-based learning is an instructional methodology; that is used to enhance learning by requiring learners to solve problems (Barrows & Tamblyn, 1981). It focuses on the problem solved by the learner by providing an authentic, ill-structured task which students will encounter in future working environments (Hung et al., 2008).

Conceptual understanding is the ability to apply a concept or knowledge already existing to different unencountered circumstances. Pines (1985) describes concepts as "packages of meaning (that) capture regularities (similarities and differences), patterns, or relationships among objects, events and other concepts" (p.108). He described that concepts vary from simple labels for entities to high level abstractions that describe complex relationships (Pines, 1985). Meaningful conceptual change learning occurs when students' prior knowledge of a particular concept is challenged and reconstructed (Strike & Posner, 1982). Students working in groups allows for student discourse to aid in the student's increase in conceptual understanding (Decristan et al., 2015).

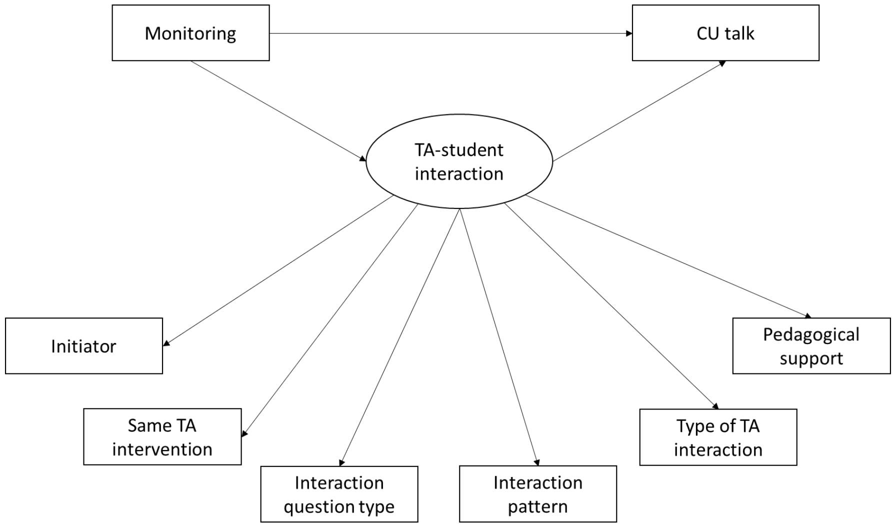
Teachers play a major role in how well students collaborate and learn. The concept of scaffolding (Wood et al., 1976) is grounded in Vygotsky's (1978) sociocultural theory's zone of proximal development (ZPD). For instructors to intervene, they must diagnose the student's current understanding of the content prior to providing the support (Snow & Swanson, 1992). Two aspects of the teacher's role in the collaborative classroom are monitoring and intervention (Kaendler et al., 2015). Monitoring allows the instructor to understand where the student is coming from, what they are struggling with and how to best approach the intervention (van de Pol et al., 2010). Research shows that instructors often do not monitor before intervening in groups, resulting in a mismatch between intervention and the group's needs (van de Pol et al., 2010; Webb et al., 2009).

Teachers often follow a traditional discourse pattern called the IRE (Initiate-Respond-Evaluate) pattern (Lemke, 1990), also called "triadic dialogue" (Wells, 1993, Dawes, 2014). Studies that examined these patterns in student-teacher classroom conversations show that they may pose barriers to student engagement and learning by positioning the instructor as the expert who is evaluating the comments of the student (Cazden, 1988; Herbel-Eisenmann et al., 2013; Wang, 2020). This is particularly problematic in contexts where the students are positioned as creating joint meaning, and yet the instructor does not demonstrate a shared role in meaning making (Krist, 2020).

The purpose of this study is to begin to investigate how TA (teaching assistant, a graduate student instructor for the discussion classroom) interacts with a group and its impact on conceptual understanding talk (see Figure 1). The model was derived from the various theoretical frameworks discussed and connects it with observable interaction factors that were coded from the video analysis. To this end, we will answer the following research questions.

1) What factors of the TA-student interaction influences conceptual understanding talk during an instructor intervention?
2) How much does monitoring affect the conceptual understanding talk during an instructor intervention?

Figure 1
Model of the Relation Between Monitoring, TA-Student Interaction, and Conceptual Understanding Talk



Methods

This study is part of a large project focused on collaborative learning in engineering courses. The implementations have focused on creating and studying a student collaborative whiteboard tool, and an orchestration tool for instructors. The implementation presented in this study used an iteration of the Collaborative Support Tools for Engineering Problem Solving (CSTEPS) student tool which is a tablet application that allows the student to interact with each other within the shared digital workspace.

Participants

The study was part of a 16-week undergraduate engineering course. Four 50-minute discussion sections were taught in a lab classroom each week. Each class had a maximum capacity of 32 students in groups of 3 or 4. Students worked in groups on synchronized tablets that provided a joint space for them to solve the task. Eighty-six students consented to participate in the study. Students worked together with their group to solve the task while the instructors facilitated the discussion session.

Each discussion section had one graduate student teaching assistant (TA) instructor and one or two undergraduate student course assistant (CA) instructors depending on the total number of students in the discussion section. The CAs were undergraduate students who had previously taken the course and excelled at it (all will be referred to as TAs for simplicity in this paper). TAs and the students consented to participate during the first week of the semester for video and audio data, log file data, and interviews.

Data Sources

Video data from all consented groups were collected on multiple weeks for the larger study. This paper focuses on data from week 12 because the week 12 task was a collaborative task that the research and teaching team had worked on extensively (Shehab et al., 2017). The week 12 task was an ill-structured design problem that had multiple solutions and students had to describe their assumptions when solving the problem. In addition, students worked in the same groups all semester, so by week 12 they were familiar with each other, and the technology they were using, reducing any issues that could arise from new groups or new technology.

Analysis

In order to understand TA-student interaction and what factors play critical roles in these interactions to enhance the conceptual understanding of the students a mixed method approach was undertaken with the qualitative video and transcript analysis providing the interaction factors which were then used to code all the interaction video data from the classroom along with its transcripts. The interactions were coded for TA-student interaction and conceptual understanding talk using coding schemes (see Table 1 and 2) developed by emergent coding using a grounded theory approach (Corbin & Strauss, 1990). This allowed for coding all the 86 interactions (the unit of analysis) in the dataset. This was followed by a statistical analysis involving Confirmatory Factor Analysis (CFA) to determine which factors were the primary estimators of TA-student interaction and what the effect of monitoring was on the conceptual understanding talk present during the intervention.

Coding Schemes

Video data was transcribed in playscript format from one minute before the TA intervention began to the end of the TA intervention. This duration of one minute was chosen because it was the maximum time taken by TAs to monitor before intervening with a student group. During the intervention, TA-student interaction was also coded for the level of conceptual understanding talk (see Table 1) as an episode level code. The first author, who designed this coding scheme, has a degree in engineering and had taught this course in the past, and was therefore highly qualified to evaluate the students' conceptual understanding talk. The TA-student interaction coding scheme (see Table 2) was developed to categorize the type of monitoring and intervention.

Table 1
Coding scheme: Conceptual understanding

Category	Code	Definition	Example
Conceptual understanding talk (CU)	High level understanding talk = 1	Conversation involves understanding why the problem is solved in this way, why a particular concept is used (more than what is needed to solve the problem)	TA: *"Are you having problems or?"* A61: *"Ah we're…"* TA: *"Huh?"* A61: *"Yeah, confused. So we're wondering, from A to the end of the beam, there's no uh deflection"* TA: *"Right"* A61: *"Um, but since there was previous deflection that means that that distance will be at an angle"* TA: *"Yes"* A61: *"So it will still counter- it- affect our- like almost overall deflection"* TA: *"Yes"*
	Low level understanding talk = 0	Conversation involves how to solve the problem and how to arrive at the solution without any reasoning	TA: *"So you should have four boundary conditions to solve for those. What are your four boundary conditions?"* A24:" So we have *Y of zero equals zero, Y prime of zero equals zero, and then Y of A equals- is equal to both of them and Y prime is equal-* "

Statistical Analysis

Descriptive statistics were generated using SPSS Ver.24 and analyses were conducted using Mplus 8.5. Path models as shown in Figure 2 were fit to the data using latent variable TA-student interaction and controlling for the effects of monitoring on conceptual understanding talk. Following Hu and Bentler's (1999) fit criteria for small samples, we used CFI ≥ 0.95 and SRMR ≤ 0.9 as cutoffs for good fit. The research questions were analyzed by using Confirmatory Factor Analysis (CFA) and tested the fit of path models using MLR estimator for non-normal variables.

Table 2
Coding scheme: TA-student interaction

Category	Code	Definition	Example
TA intervention with group before (STI)	Yes = 1	TA intervened with the same group in this discussion section before	
	No = 0	TA did not intervene with the group before	
TA monitoring (TAM)	Yes = 1	TA monitors before intervention	
	No = 0	TA does not monitor before intervention	
Initiator (INIT)	Student = 1	Student calls for the TA	*"Let's just ask"* (raises hand)
	TA = 0	TA begins conversation without student calling for the TA	*"How are we doin' here, guys?"*
Initiator question type (IQT)	Specific question = 2	Task related questions geared at a specific response	*"What's Y double prime?"*
	General question = 1	Generic question to engage the group	*"How are we doin' here, guys?", "What are you guys doing?"*
	Comment/ Suggestion/ off-topic = 0	Comment or suggestion that does not require a response	*"Make sure to write down the calculations"*
Pedagogical support (PS)	Analogies = 1	TA use analogies to interact with the students	
	Free Body Diagram = 1	TA uses FBD to explain the solution	
	Other tools = 1	TA uses other tools to explain	
	Nothing = 0	No support was used	
TA interaction pattern (TIP)	Non-IRE = 1		
	IRE = 0		
TA type of interaction (TTI)	Scaffold problem solving = 2	TA ensures that the students understand how to solve the problem and does not provide the solution directly	*"Where did this come from? This is something there?"* (Pointing on tablet)
	Provides solution to the problem = 1	TA provides the solution to the problem	
	Others (checking on group/tech issues) =0	Issues unrelated to the task	*"You guys are good. Everyone else is having problems?"* (Technical issue)

Results

Descriptive Statistics

Inter-correlations among all measured variables are shown in Table 3. The correlations shows that 1) better TA interaction was associated with more conceptual understanding talk, 2) better TA interaction patterns were associated with more conceptual understanding talk and 3) conceptual understanding talk was related to interaction question type and the pedagogical support used during the interaction.

Table 3
Intercorrelations among measured variables (N = 86)

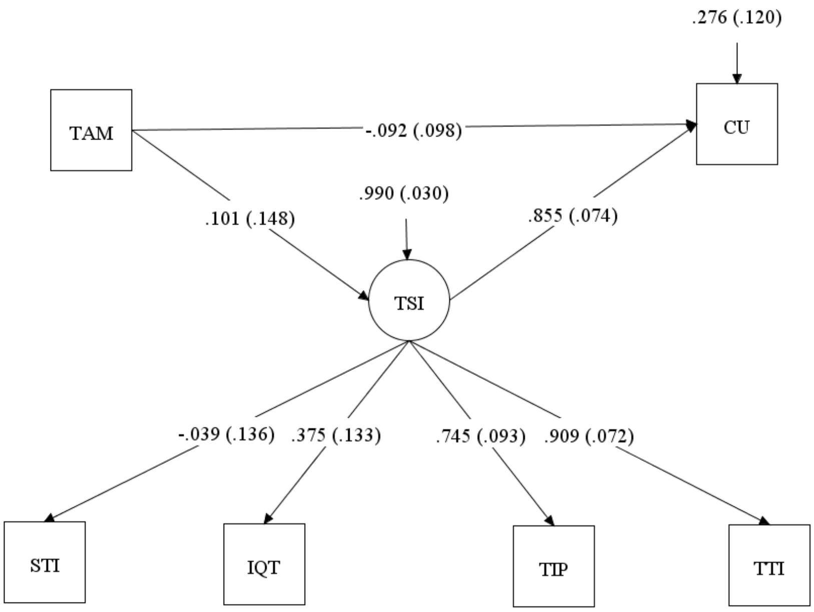
	TAM	INIT	STI	IQT	TIP	TTI	PS	CUT
TAM	-							
INIT	-.398**	-						
STI	-0.003	0.043	-					
IQT	-0.047	.274*	-0.066	-				
TIP	.212*	-0.103	-0.037	0.079	-			
TTI	0.065	-0.1	-0.091	.262*	.606**	-		
PS	-0.086	0.048	-0.163	0.166	0.167	.297**	-	
CU	-0.005	0.088	0.015	.296**	.520**	.741**	.358**	-

Note. TA monitoring (TAM), Initiator (INIT), Same TA intervention (STI), Interaction question type (IQT), Type of interaction pattern (TIP), Type of TA interaction (TTI), Pedagogical support (PS), Conceptual understanding talk (CUT)

Confirmatory Factor Analysis (CFA):

The latent variable, TA-student interaction and its corresponding endogenous variables were subjected to CFA to test whether the prescribed model based on observations are consistent. Table 4 shows the summary of the different models that were tested, the chi-squared values and its corresponding p-values, the comparative fit index (CFI), the standardized root mean square residual (SRMR) and the β-value of all the measured observable variables.

Figure 2
Estimates of the Direct Effects of Monitoring on TA-Student Interaction and Conceptual Understanding Talk



Note. TA monitoring (TAM), TA-student interaction (TSI), Conceptual understanding talk (CUT), Same TA intervention (STI), Interaction question type (IQT), Type of interaction pattern (TIP), Type of TA interaction (TTI

The direct effect of monitoring on conceptual understanding (see Figure 2) was determined by regressing conceptual understanding on the TA-student interaction (model 3) and TA monitoring and monitoring on TA-student interaction (model 3). Model 3 was selected as it rejected the null hypotheses that there is difference between the model. It was also selected to remove linear dependence between variable TTI and PS by combining the variables.

Table 4
Fit indices and coefficients for model testing (N = 86)

TSI Model	χ^2(p)	CFI	SRMR	INIT(β)	STI(β)	IQT(β)	TIP(β)	TTI(β)	PS(β)
Model 1	14.56(0.10)	0.954	0.100	-0.031	-0.164	0.361*	0.703*	1.000*	0.848*
Model 2	2.24(0.81)	1.000	0.055	-	-0.164	0.362*	0.703*	1.000*	0.848*
Model 3	0.309(0.86)	1.000	0.018	-	-0.039	0.375	0.745*	0.909*	-

Note. TA-student interaction (TSI), CFI = Comparative Fit Index, SRMR = Standardized root mean square residual, Initiator (INIT), Same TA intervention (STI), Interaction question type (IQT), Type of interaction pattern (TIP), Type of TA interaction (TTI), Pedagogical support (PS)

The results from the Confirmatory Factor Analysis (CFA) on the TA-student interaction variable indicates that the initiator does not influence the TA-student interaction. Major factors that affect the interaction are: (1) the questions being asked (specific or not) by the initiator and (2), how the TA approaches their interaction with the group (i.e., in a non-IRE format or not), and (3) the type of TA interaction (scaffolding for problem solving, providing solution or others).

The following vignette from the dataset shows how a non-IRE interaction pattern leads to conversations around concepts and how the instructor scaffolds for it. The TA begins to first understand what the student has worked on and scaffolds their thinking by following up with questions that make them come up with their own ideas and helping the student build on their thoughts.

> TA: Okay, scroll down. So, as we're breaking this beam up, ah, or as we're looking at this beam, we have two different distinct bending moments, right?
> A61: Yes
> TA: So, what you evaluated is everything to the left, I believe
> A61: Yes
> A64: Yep
> TA: We ah- we need to come up with an independent equation, right?
> A61: Yes. Well, it's just gonna be zero
> TA: The bending moment will be, but --
> A61: When you integrate, you're gonna get a constant- oh!
> TA: You're gonna get constant integration and we have an extra boun- we have an extra set of boundary conditions there for-

Discussion

This study set out to understand how the nature of instructor interaction in small groups influenced the conceptual understanding of students. The emergent coding scheme developed from the TA-student interaction was used to build a path model (see Figure 1) and CFA (see Figure 2) was conducted. Results from the CFA indicate that, when the objective of the TA was to scaffold the problem, using a non-IRE interaction pattern while asking specific questions to begin the conversation, it was associated with improved TA-student interaction.

When looking at the type of interaction, the findings mirror previous work by Wang (2020) and Kranzfelder (2020) which showed that non-IRE pattern of interaction improved the chances of students challenging each other on concepts and improving the learning experience. This result are similar to the work done by Aleven and Koedinger (2002) which found that scaffolding for problem solving improves student interaction through explanation. An emergent model for TA-student interaction was analyzed using CFA with Same TA intervention (STI), Interaction question type (IQT), Type of interaction pattern (TIP) and Type of TA interaction (TTI) as the measurable variables that identifies the TA-student interaction.

The coding of pedagogical support from a categorical variable which measured the use of tablets, whiteboards, props, etc. as a pedagogical support to a categorical variable that measured whether a support was used or not made the variable linearly dependent with the type of TA interaction variable. Therefore, it had to be treated statistically by combining both the pedagogical support variable and TA type of interaction variable into a single categorical variable with four levels based on the combination of the two variables combined. Thus, meaningful discussions along the impact of pedagogical support on the interaction and conceptual understanding could not be made.

The effect of monitoring on the TA-student interaction and on conceptual understanding did not yield significant results. The results did indicate that monitoring is a reasonable estimator of the TA-student interaction but was not significant. The TA monitoring enables them to make better decisions on how to intervene.

The direct effects were not significant for monitoring on the conceptual understanding talk. This shows that monitoring had no effect on whether the interaction between the students and the TAs involved discussions that showed deeper discussions of the concepts. But there was significant direct effect of TA-student interaction on the conceptual understanding talk. This could mean that the goals of monitoring are not necessarily to improve their conceptual understanding but to complete the task presented during the discussion. TAs might be monitoring for possibilities to help the students without explicit focus on students' conceptual understanding during their interaction with the group. TAs should be trained to monitor for opportunities to understand and improve students' understanding of the concepts they discuss when solving problem in the classroom.

Limitations in this study involve combining TAs and CAs together as instructors (referred to as TAs in this paper). TAs and CAs have varied experience within them and how they interact changes. Future study with additional dataset could look at impact TAs and CAs have separately. This question has a lot of on what TAs and CAs bring to the table and how decisions should be made going forward in-terms of training as well and the number of personnel required to facilitate such classrooms.

Conclusion and implication

Outcomes from this study have clear implications on how to provide training for TAs. Based on the estimates, TAs should focus on scaffolding for problem solving and avoid the IRE (Initiate-Response-Evaluation) pattern of discourse to improve the TA-student interaction. TAs should be trained on how to approach interventions during discussion sections by providing examples of scenarios to help them navigate through them such that they practice scaffolding for problem solving (Kim & Hannafin, 2011) and non-IRE discourse (Kranzfelder et al., 2020; Wang, 2020) which both improve TA-student interaction.

This study indicates that Structural Equation Modelling is an effective tool at capturing the latent constructs like TA-student interaction and quantify them using measurable observable variables. This allows us to statistically verify the interdependencies between variables and how they relate to each other. Using confirmatory factor analysis, a working latent variable (TA-student interaction) was described using measurable variables. It was able to show that interaction pattern and the type of questions asked by the instructor impacts the intervention. It also showed that the initiator does not play a role in the way the interaction proceeds.

There was no significant effect of monitoring on conceptual understanding talk. However, the descriptive statistics indicated a high correlation between conceptual understanding talk and TA interaction pattern and TA type of interaction suggesting that there is more to be explored than was possible within the limitations of the data available for this paper.

Future work involves understanding how the students worked after an intervention and how student uptake relates to their task performance. This information can inform best practices for how instructors should intervene and how it will affect the student group. This dataset also contains log files from the synced tablets the students used while collaborating with their peers. Data mining techniques can be applied to understand patterns of student behavior before and after intervention and could be added to the emergent model described in this paper for better understanding of the intervention process.

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