Theoretically Framing a Complex Phenomenon: Student Success in Large Enrollment Active Learning Courses

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Student success in large enrollment undergraduate science courses which utilize "active learning" and Learning Assistant (LA) support is a complex phenomenon. It is often ill-defined, is likely impacted by many factors, and regularly interacts with a variety of treatments or interventions. Defining, measuring, and modeling student success as a factor of multiple inputs is the focus of our work. Because this endeavor is complex and multifaceted, there is a need for strong theoretical framing. Without such explicit framing, we argue that our findings would be uninterpretable. In this paper we describe our efforts to define that theoretical framework, present the framework, and describe how it defines our methodological approach, analyses, and future work.

I. INTRODUCTION

There is strong evidence that the implementation of active learning methods in undergraduate science courses can lead to increased student conceptual understanding and course achievement [1]. There is also evidence that Learning Assistants (LAs) [2], a practice embedded resource, can support the use of active learning methods in the large lecture science classroom [3]. Active learning is a term generally used to describe interactive innovations in undergraduate science teaching, similar to the notion of interactive engagement (IE) used in physics education research [4]. Wieman offers a definition of active learning, in which "students are spending a significant fraction of the class time on activities that require them to be actively processing and applying information in a variety of ways, such as answering questions using electronic clickers, completing worksheet exercises, and discussing and solving problems with fellow students" [5]. But we also know that not all of these innovations in undergraduate science teaching practices (i.e., active learning or interactive engagement) contribute equally to student level outcomes [6]. Though researchers have many ideas for why active learning helps students learn, achieve, and persist in a course, we do not know what specific characteristics of active learning contribute the most to these outcomes, or the mechanisms by which these activities work. Further, it is unclear how LAs support contribute to student success in these courses. It is time to look more deeply at the contributions of different observable characteristics of active learning methods to student success [5].

In our work, we observe, characterize, and interpret the active learning methods employed in a large sample of LA supported and non-LA supported science courses at the University of Colorado Denver, North Dakota State University, and Florida International University. We define *student success* as concept inventory learning gains, course achievement, retention, and persistence.

In this paper, we outline our research problem via four main research questions (Section II), describe the theoretical framework we are employing to frame our complex research problem (Section III), and discuss the resulting data collection and analyses (Section IV) that are currently being conducted to answer our research questions.

II. RESEARCH QUESTIONS

Our research questions are: 1) What are the characteristics of active learning tasks employed in undergraduate science courses?, 2) How can the design and implementation of active learning methods be understood in terms of a theoretical framework?, 3) How are LAs involved in supporting active learning?, and 4) How does engaging in these active learning methods with and without LA support contribute to student level outcomes? We are engaged in identifying and characterizing the use of active learning methods in LA and non-LA supported large lecture science courses, and using a framework to map those activities to the learning processes they target. We then plan to model student level outcomes (e.g., learning gains, course grades, course retention, and two-year persistence) quantitatively as a function of variables at both the course level (e.g., assigned instructional tasks) and student level (e.g., a student's interaction with other students or LAs), and interpret those models with respect to the theoretical framework. Finally, we will build qualitative arguments about the activities and outcomes observed in these courses. We will then be able to synthesize our quantitative modeling and qualitative arguments in order to describe the characteristics of LA and non-LA supported classroom activities that contribute most to student outcomes, and link those outcomes to specific learning processes. Although we have not yet answered these questions, this paper is about the theoretical framing which underpins and binds the entire research program.

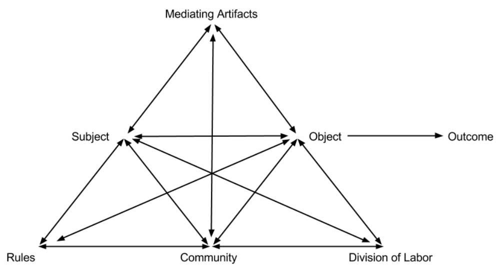

FIG. 1. The Activity System.

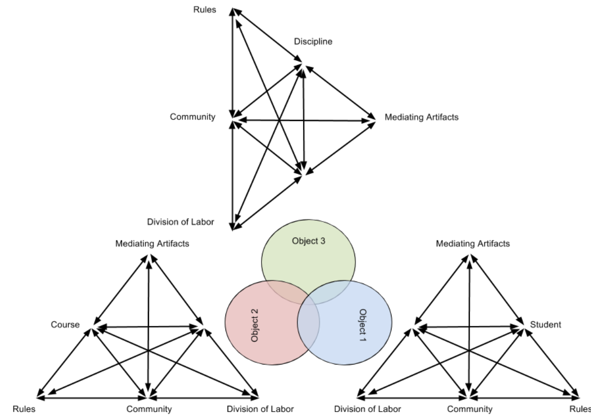

FIG. 2. Three interacting activity systems.

III. THEORETICAL FRAMEWORK

Because our ultimate research question is focused on individual student level outcomes (learning gains, course grades, course retention, and persistence in major), one might argue that a purely cognitive theoretical framing might be appropriate for our work. These outcomes can be directly tied to latent constructs that are conceptualized as residing within an individual student's head (e.g., conceptual understanding within the domain). As such, framing within something like Conceptual Change Theory [7] might be warranted. However, we are also keenly interested in the social construction of knowledge and student engagement. Many of the "active learning" activities are, by definition, interaction-based. Therefore a more social cognitive theory of learning [8] might be appropriate, or even a sociocultural or situated theory [9, 10] owing to the complexity of classroom and student cultures which mediate individual student learning. Due to the complex nature of our target phenomenon and our multifaceted units of analysis, we find ourselves arriving at the "Learning Paradox", the boundary between cognitive and cultural approaches to learning and development [11, 12]. We are certainly not the first to approach this boundary from a practical, theoretical-need standpoint [13]. What is needed to help frame our work is more of a metatheory which draws on appropriate aspects of these different theories of learning.

The metatheoretical framework of Cultural Historical Activity Theory (CHAT) [11, 14] addresses these complexities and needs. In particular, the dialectic nature of CHAT affords us the opportunity to consider multiple, seemingly discordant units of analysis (e.g., individual/collective) which can be conceptually isolated from one another, but still must be understood together to make sense of the target phenomenon. In CHAT, the activity system builds on Vygotsky's notion of mediation [10], and in its basic form is represented in the "activity triangle" (see Fig.1).

In our basic activity system, the Subject is the student, the Object is student success, and the Outcome represents the way student success is operationalized (learning gains, course grades, course retention, and persistence in major). The Activity itself is learning science. Where the activity system conceptualization is particularly powerful is in representing the situated nature of the Subject>Object>Outcome space within the classroom Community, wherein sets of Rules and a Division of Labor help to define that Community as they engage in the Activity. The Mediating Artifacts by which students work toward success could be at the individual level (e.g. student work, notes, products) or at the community level (e.g., group constructed responses, projects, etc). The link between Community and Mediating Artifacts in the activity triangle represents the engagement of the class with the activities. The focus in the activity system is on the complex interrelationships between students and their community, while still considering the individual outcome space as a unit of analysis [15], hence the need for dialectic thinking.

An important aspect of our work is the notion of interacting networks at various levels as parts of a larger system. For example, students (the Subject in our basic activity system) are nested within courses, that are in turn nested within disciplines. This nested structure lends itself nicely to quantitative analysis using Hierarchical Linear Modeling (HLM; discussed further below) but can that analysis be justified by interacting networks of multiple activity systems? Indeed, the "third generation" of CHAT does just this, and considers at a minimum two (and in our work three) interacting activity systems (see Fig.2).

In this set of three interacting activity systems, the ultimate object of interest is still student success. But there are three objects (at the student, course, and discipline levels) that interact to contribute to a single, object-oriented conceptualization of student success. Students themselves contribute characteristics, experiences, and motivations towards their own success. Accordingly, the Student is the Subject and student success is still the Object in the activity system on the lower right (see Fig.2). Course structures, curriculum, and instruction also contribute to student success, therefore the Course is the Subject and student success is still the Object in the activity system on the lower left (see Fig.2). And finally, disciplinary knowledge structures, norms, and cultures also contribute to student success. In the activity system on the top of Figure 2, the Discipline is the Subject and student success is again the Object. Communities exist within and across each of these interacting systems. The complex interaction of these three levels of the object comprise our object of ultimate interest: student success within the systems.

IV. METHODOLOGY

The interacting activity systems depicted in Figure 2 help to define our data collection and analyses. Research question 1 (What are the characteristics of active learning tasks employed in undergraduate science courses?) is focused on mediating artifacts in the course level system. Research questions 2 and 3 (How can the design and implementation of active learning methods be understood in terms of a theoretical framework? and How are LAs involved in supporting active learning?) are focused on community, rules, and division of labor (if the activity is social) in the course level system. Finally, research question 4 (How does engaging in active learning with and without LA support contribute to student level outcomes?) is focused on the interacting resultant object of all three activity systems. In this section, we discuss the instruments we have identified, adapted, or developed for data collection and analysis, and the quantitative analyses we propose in order to answer each of the research questions.

A. Characterizing Mediating Artifacts

The Mediating Artifacts of our activity system correspond to the active learning tasks students engage with in the classroom. We are concerned with identifying the types of active learning being used, and with characterizing the tasks as a means of developing a set of predictor variables for our quantitative models (see Section IV C) and to build descriptors for our qualitative arguments.

To identify the types of active learning methods, we are observing classes using the Classroom Observation protocol for Undergraduate STEM (COPUS) [16]. The codes from the COPUS that we note as active learning types are 'individual thinking or problem solving', 'discussing clicker questions', 'working in groups on a worksheet activity', 'other assigned group activity', and 'engaged in whole class discussion'. The types of active learning methods used and their frequency are possible variables in our quantitative models.

To characterize the Mediating Artifacts further, we need to analyze the tasks involved. Our decision for what analysis to execute is based on what task characteristics we think will have the greatest impact on student success in science courses. Our hypothesis is that students will be more successful in courses where they engage in 'authentic' tasks. By 'authentic' tasks we mean tasks where students do activities that scientists actually engage in, in ways that scientists do. This is consistent with the definition given by Brown et al. [17] who take a situated view of knowledge. They state that practitioners typically engage in reasoning that utilizes causal models to solve ill-defined problems and suggest that students gain conceptual understanding through an apprenticeship where they engage in the practices of a domain.

The concept of three-dimensional learning [18] promotes the integration of scientific practices, concepts that span the science disciplines, and disciplinary core ideas in developing tasks. Not only does engaging in scientific practice align with the way we described authentic activity above, but also focusing on a few central concepts creates further alignment because it is around those that science practitioners organize and contextualize their knowledge [19]. Although originally developed for K-12, we contend that the concept of three-dimensional learning applies equally well to post-secondary classrooms because of the importance of authenticity. The Three-Dimensional Learning Assessment Protocol [20] was designed, in part, to determine if assessment tasks are likely to prompt students engagement with the three dimensions. We are using the protocol to characterize the active learning tasks being used in the courses we are observing. Again, we will develop this characterization into predictor variables in our quantitative models. We will interpret how well aligned the task is with three-dimensional learning as a measure of the authenticity of the task.

B. Characterizing Community

We are constraining the bounds of Community for our science learning activity system to the classroom. This means that the Community will consist of the students, the instructor, and the LAs (if it is an LA-supported course). There are three types of interactions that we are aiming to characterize within the Community: student-student interactions which we will examine through student surveys to define the classroom network space and each member's position in that network [21]; instructor-student interactions which we will look at through student action COPUS codes ('answering a question', 'asks a question', 'engaged in whole class discussion') and instructor action COPUS codes ('answering questions', 'moving through class guiding ongoing student work during active learning task', 'one-on-one extended discussion with one or a few individuals'); and LA-student interactions characterized by codes similar to instructor codes from the COPUS.

In characterizing the link between Community and the Mediating Artifacts we are concerned with determining the extent to which students engage with each other and the tasks, and the extent to which instructors and LAs facilitate that engagement. Class-level engagement will be measured based on Chi's Interactive>Constructive>Active>Passive framework [22] and the other pieces will be measured through the frequency of the Community interaction codes described above.

C. Building Quantitative Models

Because our object of interest is viewed as existing within three interacting activity systems, and because those systems exist at different levels (due to the nestedness of students within courses within disciplines), we are using Hierarchical Linear Modeling (HLM) [23] to model and help make sense of the outcome measures. In using HLM, we take very seriously the challenge of defining the model variables with "precise meaning so that statistical results can be related to the theoretical concerns that motivate the research" [23]. CHAT helps us to do that in a way that addresses the dialectic nature of these data and the complexity of the object of interest.

Our initial quantitative models will be run with two levels (students within courses), as our current data collection is focused there. For now, the discipline level exists only conceptually to help our framing and interpretation of the object of measurement. Outcomes to be modeled include student gains on concept inventories, course grades and drop/fail/withdraw likelihoods, and persistence in major. At the student level (level 1) the following predictors will be included in the model (as random effects): student engagement, gender, ethnicity, Expected Financial Contribution, GPA. At the course level (level 2), the following predictors will be included to model randomly varying slopes at level 1: course activities variable, class engagement variable, instructor actions variable, Learning Assistant actions variable.

Without an explicit theoretical framing, the relative contribution of each effect (i.e., slopes in regression equations) on student outcomes would be only minimally interpretable. For example, any effect due to socioeconomic status (for which Expected Financial Contribution is a proxy) cannot be disentangled statistically or substantively from any other predictor variable unless considered in concert with other factors in the interacting activity systems. These potential interactions must not only be understood statistically, but also theoretically.

V. DISCUSSION AND FUTURE WORK

Although we have yet to answer our research questions, our current efforts are strengthened by the CHAT framework. Importantly, the dialectic, object-oriented nature of CHAT will help us to make sense of a complex object (student success) in a set of interacting activity systems at multiple levels: student, course, and discipline. Our current challenges are to define our data in meaningful variables which can be modeled quantitatively. The operationalization of the variables will be informed by our qualitative arguments and interpretations, considering other data sources from each of the interacting activity systems. In the future, we also plan to characterize the discipline level in a way that can contribute to the quantitative models.

ACKNOWLEDGMENTS

This work is supported by NSF DUE award 1525115, and this paper is Contribution No. LAA-040 of the International Learning Assistant Alliance.

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