Developing and Supporting STEM Undergraduate Teaching Assistants as Partners in Teaching

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***Abstract*—Research to Practice Full Paper: The reliance on undergraduate students to take on key aspects of college level courses, such as grading, holding office hours, and facilitating small group work, has been growing with the increased enrollment in many introductory STEM courses. There is an urgent need to understand how these undergraduate teaching assistants (UTAs) approach and engage their roles in the wake of the increasing dependency on these students to facilitate learning within courses. Over the past few years at Brown University, and many others, UTAs have been hired at a growing rate and have been expected to take on new responsibilities. However, institutional policies and guidelines have not changed to reflect these new conditions, raising the question as to what are points of tension in the UTA experience and what are the causes of such tensions. This paper aims to address this concern by identifying and analyzing these tensions that arise as UTAs work to be successful educators.**

To further understand the tensions and pressures experienced by these student workers, we interviewed UTAs in engineering, physics, computer science, and one UTA in engineering and computer science (n=5). The departments vary according to the size and scope of their respective UTA programs. We use the framework of Activity Systems Analysis (ASA) in an effort to identify areas of tension and improvement in current teaching and support practices. The ASA framework allows researchers to narrow their focus on human activity and experiences, in this case those of the UTA, while not losing sight of the cultural and historical contexts in which this activity and these experiences take place. The framework also allows for the identification of systemic tensions that tie human activities and environments to undesired outcomes at an individual or systemic level. We identify tensions from the UTA experiences, provide recommendations for ways to better support and develop STEM UTAs, and identify future areas of research.

***Index Terms*—activity systems analysis, undergraduate teaching assistant, peer educators, pedagogical development, students as partners**

I. Introduction

Colleges and universities have been faced with rising enrollments in introductory courses with limited faculty and staff resources. Many of these institutions have started introducing undergraduate students in teaching roles in these classrooms as a way to improve the student learning experience [1]. Although there is no standardized way to engage undergraduate students in teaching, many institutions have started using the Learning Assistant (LA) model developed by the University of Colorado Boulder. The LA program has a structure and process for the hiring, pedagogical development, and implementation of LAs, meaning institutions that choose to implement it do not necessarily need to devote resources to creating a robust program from scratch [2]. The engagement of undergraduate students in teaching happened well before the implementation and popularization of such a well established program. One of these institutions is Brown University, which has worked with undergraduate students as teachers for several decades now [3] in many STEM contexts. As there have not been many studies on large Undergraduate Teaching Assistant (UTA) programs that do not deliberately follow the LA model, there is a gap in knowledge in how these programs support and develop these undergraduates and how effective these undergraduates are as teachers.

If institutions move towards working with UTAs and LAs as a way to improve student learning, we need to better understand the experiences of UTAs on a deeper level. Brown University relies on UTAs across multiple departments and for various responsibilities. The Computer Science (CS) department even advertises their large and successful UTA program in attempts to recruit more students. Yet there is not much information about the specific responsibilities or opinions voiced by these UTAs that is publicly available, which points to an under examination of the successes of this program from the UTA perspective.

We aim to study the UTA experiences and support structures at Brown University by applying Cultural Historical Activity Theory (CHAT) using Activity Systems Analysis (ASA), which has yet to be applied to research involving undergraduates as educators. We ask the following four key research questions:

1) *Roles and Responsibilities*: What are the roles and responsibilities of UTAs at Brown University?
2) *Needs for Success*: Under individual definitions of success, what do UTAs see as necessary support for them to be successful in engaging in their UTA responsibilities?
3) *Existing Support*: Do these support mechanisms manifest in UTAs' interactions with faculty/staff/administration?
4) *CHAT Application*: What tensions arise as UTAs work to be successful educators?

II. Background

Training and development programs are being popularized by institutions that hire many undergraduate teaching or learning assistants (e.g., [4], [5]). The LA program, developed and popularized by the University of Colorado Boulder, used by more than 200 institutions [6], requires all LAs hired each year, which now amount to about 400 student workers, to attend a course dedicated to providing "practical techniques as well as readings from cognitive science, learning theory, and physics education research" [7] for students taking on the role for the first time. Other institutions have workshops lasting the entire term that are less time and work intensive to provide similar preparation and training for their UTAs [8].

The popularity of the LA program has likely benefited from the years of studies and resources published on the successes and shortcomings of the program. For example, Talbot, Hartley, Marzetta, and Wee [9] show how the relationship between the introduction of LAs in courses can boost student gains. UTA and LA programs also tend to benefit the student employed in areas such as providing confidence, teaching skills, and community building [1].

While there are benefits to implementing the LA program, there are areas for improvement. The study outlined in Campbell, Malcos, and Bortiatynski [8] reveals overall perceptions of success in the Pennsylvania State University's Eberly College of Science LA program. Within this article, researchers identified the relative weakness of professional development as part of the LA program, which can now be addressed by the institution. The evaluation of such programs could also illuminate patterns of exploiting student workers, such as not paying them for being "on-call" or performing duties that fall outside their job description [10].

At Brown University, a private ivy-league research university with approximately 10,000 students (undergraduate and postgraduate), there is a large population of UTAs, up to 750 a year across multiple departments. UTAs at Brown University take on a variety of roles, many of which are similar to those of an LA. UTAs are undergraduate students who facilitate peer learning either in one-on-one (e.g., office hours) or group (e.g., group problem solving sessions) settings. The roles, development, and implementation of the UTAs was not created with the LA program in mind. There is no centralized program for recruiting and hiring UTAs. Each department and faculty have their own process and expectations for hiring and until recently, trained students according to their specific context, if at all. Since Brown University has not published or evaluated the existing support systems for students working as UTAs, by default the current practices are not informed by any current and relevant studies into the existing support and development structures available. Additionally, the lack of research into the university's program could be hiding student work malpractices.

A. Cultural Historical Activity Theory

Environments in which UTAs facilitate learning are complex. Individual UTAs interact and navigate broader systems and contexts they are a part of such as the classroom or the university. These systems vary in scale and influence, but need to develop an understanding of how UTAs envision their success and how the institution, at many levels, currently engage students toward this success.

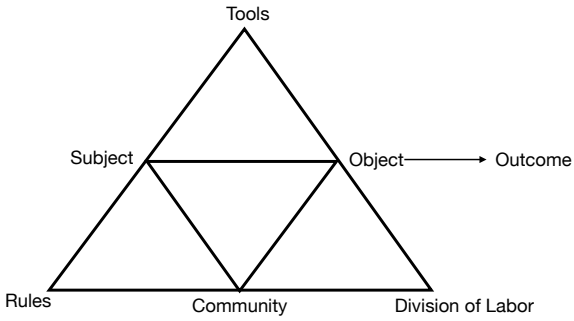

Fig. 1. Engeström's Activity Systems Diagram.

To analyze how the individual is shaped by and shapes their context and environment, we apply the Cultural Historical Activity Theory (CHAT) framework using Activity Systems Analysis (ASA) [11]. CHAT, as laid out by the psychologists Lev Vygotstky and Aleksei Leontiev, makes use of "'cooperative, goal-directed, artifact-mediated activity'" as the base unit of analysis in understanding interactions between a subject and their environment [12]. Yrjö Engeström contributed to this framework by creating a visual diagram, shown in Fig. 1, which displays "the ways a subject's actions on an object with the aid of mediating artifacts is related to the community activity system in which it occurs" [12]. In other words, it is a visual representation of a single activity system with all its components laid out. These components, are [11], [12]:

- Subject: the individual or groups of individuals.
- Tool: resources used by the subject.
- Rules: values, regulations and conventions that affect how the activity takes place.
- Community: the social group or groups the subject belongs to as related to the activity.
- Division of Labor: how labor is sectioned and shared among the community.
- Object: goal or motive of the activity the subject is usually aware of.
- Outcome: the end result of the activity, which may or may not be similar to the object.

The visual representation of an activity system can help the researcher identify contradictions in the interactions between components of that system [11]. A contradiction is a disconnect or mismatch between the expectations set up between two components. For example, a teacher in a classroom might be responsible for assigning students homework (a responsibility under Rules) but may not have enough textbooks for all their students (a resource in Tools). This is a contradiction since the relationship and reliance between the Tools (enough textbooks) and Rules (assigning homework from the textbooks) is not being fulfilled. These contradictions are then used by the

researcher to infer tensions that might exist in the activity system. These tensions usually reveal barriers that prevent the subject from achieving their object and can support theories that explain the differences between the objects and outcomes of a particular activity system.

CHAT has been used in higher education contexts. For example, Kinti and Hayward [13] used CHAT as a way to understand the relationship between professor and student in the undergraduate research context and was able to indicate learning experiences that might help student researchers develop their research capabilities. Turpen and Finklestein [14] used CHAT to compare and contrast two approaches to teaching large undergraduate introductory physics lectures and how the modification of either institutional structure or individual teaching style affected the activity system analyzed. Applying CHAT to the context of higher education and the study of UTA programs both have precedent, however there has not yet been an application of CHAT to understand the UTA experience, support, and development structure, which this paper aims to do.

CHAT is not without its limitations and critiques. Yamagata-Lynch [11] identifies the primary ways in which it has been shown to be flawed and proposes ways researchers can address these concerns through the research process. There are two main critiques that are relevant to this study: the inability for applying ASA to reach generalizable conclusions [15] and the simplifying of reality of the framework. While these are limitations to the framework, our study is not meant to be generalizable to the entire UTA population at Brown University, but to seek a better understanding of the experiences of UTAs. Additionally, while ASA might not be able to capture the full range of our participants' behaviors and experiences, we believe the use of the framework is enough to identify key tensions that manifest within the activities of each participant. We will use these tensions to inform future studies in an effort to create guidelines and pedagogical development for UTAs at Brown University.

III. Methodology

A. Participants and Setting

Students were recruited through a form sent to the School of Engineering, Computer Science, and Physics departments. Within the form students were able to provide brief information about themselves (class year, major, number of terms as UTA, classes UTAd). We received 30 responses, with the majority of the responses coming from the Computer Science department, from which we identified participants from different class years and different course levels to conduct interviews to try to capture a wide breadth of experiences. A few engineering students responded, but most of those respondents had UTAd non-major courses in the Engineering School mostly related to business and entrepreneurship, narrowing our scope to two Engineering UTAs. The Physics department had recently started hiring UTAs, which may explain why no Physics UTAs responded to the form. We reached out to physics professors of two courses we knew had worked with UTAs and directly to students we knew had been past UTAs. One of which we were able to interview. Table I provides information about each participant. Names are pseudonyms to protect anonymity.

TABLE I
TA Interviewees Pseudonyms and TA Experiences.

Pseudonym	TA Experience
Julia	Has been a UTA for several terms working for two versions of the same Physics class (one for students majoring in Physics and one for non majors).
Benjamin	Was a first time UTA working for an intermediate Engineering course that is a requirement for most, if not all, Engineering majors.
Daniel	Has been a UTA for an introductory engineering course once and has since then been both a UTA and a Head UTA for several Computer Science courses, some geared toward majors and others not.
Emma	Has served as a UTA for several different departments including Computer Science but had not been, at the time of the interview, a Head UTA.
Camila	Has served as a UTA and Head UTA for many Computer Science courses, some geared toward majors, others not.

Our interview pool is relatively small and the students interviewed demonstrated a high involvement in the institution's UTA programs as most were repeated UTAs or Head UTAs (HTAs). We do not view this as a debilitating limitation given the scope and intentions of this research study since it does not aim to make any generalizable claims about the UTA experience as a whole at Brown University and serves as a preliminary investigation into the roles, interactions and support mechanisms that the participants interact with.

B. Data Sources and Collection

We conducted one hour semi-structured interviews with five UTAs: two from Computer Science, one from Engineering, one from Engineering and Computer Science, and one from Physics. Each interview was recorded and used as the primary data source to provide an in depth [16] recounting of individual experiences. The questions for the semi-structured interviews were informed by the three areas of interest (roles and responsibilities, needs for success, and existing support) and the ASA framework, a sample of which can be found in Table II. The interviews were analyzed using the CHAT components to identify themes. To bound our context we assumed that the object of the activity systems was that UTAs wanted to be successful in their work. With responses coded as components, activity systems were then created using the work of being a UTA as the context. Each researcher independently coded two interviews and created activity systems. We then checked our coding and systems with one another to validate the process. Once individual activity systems were developed from the interviews, we identified contradictions between existing components of an activity system that might result in tensions which result in an undesired outcome of the system. These contradictions inform recommendations or conclusions drawn from our answers to the research questions.

TABLE II
SAMPLE OF INTERVIEW QUESTIONS.

- Why did you decide to become a TA?
- What are your responsibilities as a UTA?
- How do you prepare to enact these responsibilities? What resources do you use?
- Which of these responsibilities did you feel most prepared to engage in? Which of them did you feel least prepared to engage in?
- In your current or past experience, what responsibilities do you believe you are/were able to fulfill successfully? Which ones did you find you were not able to fulfill successfully?
- What helped you become successful in fulfilling the responsibilities you were successful in?
- What prevented you from becoming successful in fulfilling the responsibilities you were unsuccessful in?
- What do the interactions look like with other UTAs in your course? How often?
- What do the interactions look like with the instructor in your course? How often?
- What does it mean to be a successful TA in your course? Why?

IV. RESULTS AND DISCUSSION

In order to address Research Question 1: *Roles and Responsibilities*, we assembled the interviewees into four categories, Computer Science HTA, Computer Science UTA, Physics UTA, and Engineering UTA, and assigned responsibilities to each of these roles in Table III. We identify the support mechanisms that UTAs used in order to engage in these roles and responsibilities, addressing Research Question 2: *Needs for Success* and Research Question 3: *Existing Support*. We then present activity system diagrams (Fig. 2 through Fig. 5), which we use to analyze tensions in UTA activity and, from these tensions, address the ways in which the institution is not functioning as a support mechanism for UTAs, once again addressing Research Question 3.

A. Roles, Responsibilities, and Current Support Mechanisms

Many of the participants we interviewed, especially in the Computer Science department, had worked for multiple courses both as UTAs and HTAs. For cases such as these, we asked the students to share their experiences within the context of each class. As a consequence, the duties outlined in Table III are an amalgamation of the UTA duties we found pertaining to each role. Roles and responsibilities are presented in the table beginning with activities and interactions that require minimum involvement or preparation on the part of the UTA, to those that require higher engagement, which happen to be more uncommon. As an example, Camila was only required to attend lectures in one of her HTA experiences, but consistently met with the course professor in every HTA experience.

Table III lists responsibilities that vary not only between disciplines and departments, but also between courses within departments. These responsibilities usually include some face to face interactions with students, be it through Physics labs or Computer Science office hours, which come with an expectation of UTA preparation. However, the amount and type of these interactions vary. For Physics UTAs the preparation involves learning to use complex equipment for students whereas for Computer Science UTAs, the preparation aspect includes mostly learning the material. There is a lack of standardization of UTA expectations across courses of the departments we investigated leading to a diverse set of experiences and responsibilities attached to different UTAs. In order to parse the many responsibilities we identified through interviews, we group these responsibilities into four main categories of student interactions, course development, grading, and course management while also identifying the support mechanisms used by UTAs to engage in each of these duties.

TABLE III
UTA ROLES AND RESPONSIBILITIES GROUPED BY DEPARTMENT AND UTA CATEGORY.

Roles	Responsibilities
Julia (Physics UTA)	• Holding four sets of two to three hour lab sessions per term. • Preparing for and attending one hour weekly workshop sessions. • Weekly half hour meeting with professor.
Benjamin and Daniel (Engineering UTAs)	• Preparing for and holding two hour lab sessions or grading or weekly office hours. • Preparing for and holding weekly office hours. • Attending group TA training for each lab. • Holding eight two hour lab sessions. • Grading labs.
Daniel, Emma, and Camila (Computer Science UTAs)	• Attending three day to one week Head TA and professor led "TA Camp" before the start of the term. • Participating in course development prior to and during the term. • Holding weekly office hours (two to four hours). • Holding weekly labs/studios (up to two hours). • Attending weekly grading. • Attending weekly staff meeting.
Daniel and Camila (Computer Science Head UTAs)	• Computer Science UTA responsibilities. • Logistical duties such as reserving rooms. • Weekly meetings with the professor. • Managing UTAs. • Creating and managing course policies. • Managing course website. • Managing grades. • Attending lectures.

1) Student Interactions: There are three primary ways in which UTAs interacted with students in their courses: labs/studios, office hours, and virtually. Based on the conducted interviews, we see that these interactions with students are a crucial part of the experience of many UTAs. For many UTAs in fact, this is the bulk of their work responsibilities. Julia's course, for example, has a lab component that is held through a partnership between a UTA and the graduate HTA. UTAs and the HTA receive specialized training for the first lab in the term. Her other main responsibility is facilitating workshops, an optional portion of UTAing which involves guiding groups of students through weekly problem sets with HTA support. In her most recent experience UTAing this course, the professor required all UTAs interested in holding workshops to attend a university-wide UTA Orientation held

by Brown University's Center for Teaching and Learning. In both workshops and labs, Julia made use of her past knowledge and materials when she took the course herself, the answer key when it was made available, online searches, or asked her HTA "every now and then" for support.

For the two Engineering students we interviewed, labs and office hours were structured in a similar way. Daniel worked in an introductory engineering course and mentioned being "in charge of a two hour lab every week." Benjamin, when preparing to hold labs, would attend a mandatory lab training held by Engineering faculty and staff and was provided with lab guidelines and a grading procedure document that covered "all the labs" throughout the term. Benjamin experimented on his own with how he held office hours, switching from a model of "standing in front of the class and calling out people who raise their hand" to visiting groups of students in the classroom and "having a conversation" with each of them. Benjamin credited this ability to iterate on his teaching approaches to "The Theory of Teaching and Problem Solving," a course run by the Center for Teaching and Learning at Brown University as part of the Problem Solving Fellows program. The same course also taught Benjamin to "look at problems from different perspectives" when preparing to hold office hours. Although being equipped with these teaching skills, Benjamin expressed an interest in collaborating with his fellow UTAs and receiving "input from them."

For Computer Science UTAs and HTAs, interactions with students were both in person (through office hours, project design meetings, and labs) and virtual in nature (through an online Q&A forum used by many courses in the Computer Science department). UTAs have a chance to practice holding hours during UTA Camp, a "full work week" before classes start every term dedicated to preparing assignments as well as holding "mock hours" facilitated by returning UTAs and HTAs for the benefit of first time UTAs. Emma also pointed to asking her fellow UTAs for help during hours, the weekly staff meetings where UTAs would go over assignments, and the departmental UTA training held every term as resources for holding hours.

2) Course Development: Course development is a responsibility that is particular to the three Computer Science students we interviewed and happens primarily during UTA Camp. However when speaking of her experience as a UTA, Camila also mentioned rewriting "a couple of the lectures" during the term. She also mentioned having to go through a "research process" as part of the assignment creation. As an example of this research process, Camila would be given an assignment topic and then would have to search for data sets that might allow students to apply relevant statistical methods they were expected to learn. Emma's experience with course development was heavily guided by the HTAs and the professor of her course.

3) Grading: All interviewees except Julia identified grading as an important and time intensive aspect of their UTA experience, which, like many other responsibilities, varied greatly by department, course and role. UTAs are generally assigned submissions to grade on a deadline and are given a rubric or guidelines to do so. Emma pointed to a clear rubric and grading infrastructure (such as an automated grading script) as tools that facilitated grading. For HTAs Daniel and Camila, grading was much more significant and was just one of many aspects of being in charge of course management. Camila spoke of a class where the HTAs were "pretty much in charge of everything," including "calculating final grades [. . .], seeing every single grade," and "entering grades." She also described the process of rubric creation as a partnership between HTAs and UTAs, where the HTAs would assign deductions and would then seek out feedback from UTAs as to the fairness of the deductions.

4) Course Management: Managing courses is typically a responsibility that falls on professors and HTAs. Daniel, when acting as HTA, described himself as "being the person at the top of the food chain." To him, this meant "keeping track of all grades," "responding to grade complaints," and "organizing everything," including reserving rooms, managing other UTAs, managing course scripts (such as those for handing in assignments and grading) and releasing assignments through the course website. Camila also mentioned "creating policies" (such as choosing grade deductions for late assignments) and "rubric writing" as additional responsibilities she had to take on. Both pointed to returning or past UTAs and HTAs as significant inspiration for how to engage in the more logistical and managerial tasks of their jobs.

Emma's interview allows us to identify some of the roles UTAs take on that are not necessarily explicitly stated. Emma mentioned "crisis management," mostly regarding the "emotional aspect of managing all these students," as an additional responsibility that is usually not put "on paper" in the job description. Office hours for Computer Science UTAs usually involve making use of an online queue system for students to sign up. The amount of queued students has been known to reach the thirties or the sixties during more intense weeks. These long lines require UTAs holding office hours to deploy management skills, such as attending to students who were mistakenly not seen and making decisions on how many students should be seen that day.

B. Tensions and Gaps in Support

From the roles and responsibilities described above we were able to create four activity systems. Although the activity systems differ in subject, many of the components of each system overlap. The subject in each system is defined by their role, UTA or HTA, and department. The dashed lines in each activity system represent contradictions in the activity between different components of the system, which result in tensions that affect the activity as a whole. Additionally, these activity systems all exist within the context of the course the subject is UTAing. Sometimes this boundary is crossed, such as the Tools used by many of the subjects, which often extend this context. We categorize tensions into three areas: student-UTA tradeoff, professor involvement, and engaging in responsibilities.

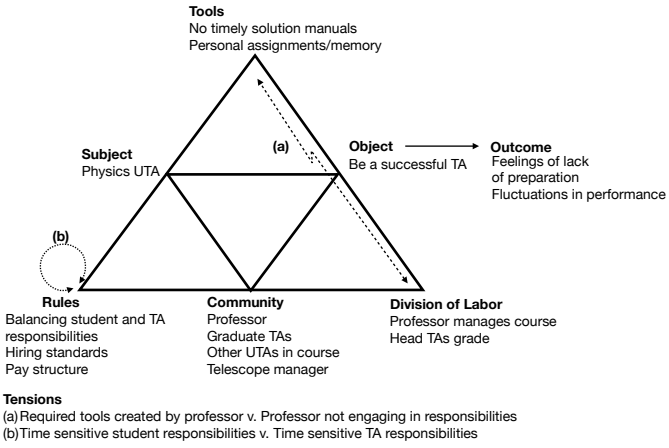

Fig. 2. Physics UTA Activity System Diagram.

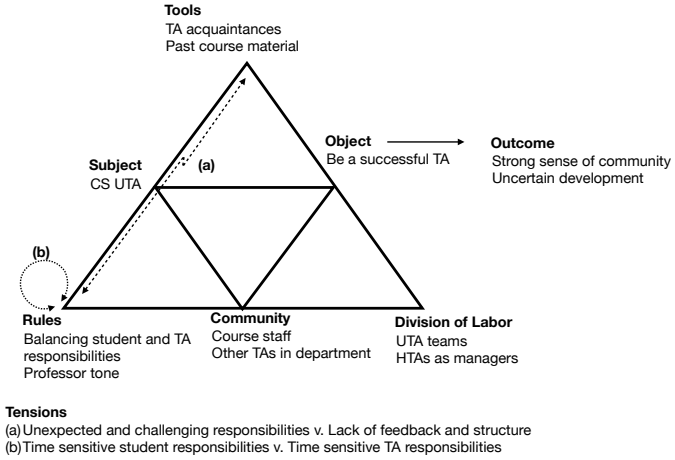

Fig. 4. Computer Science UTA Activity System Diagram.

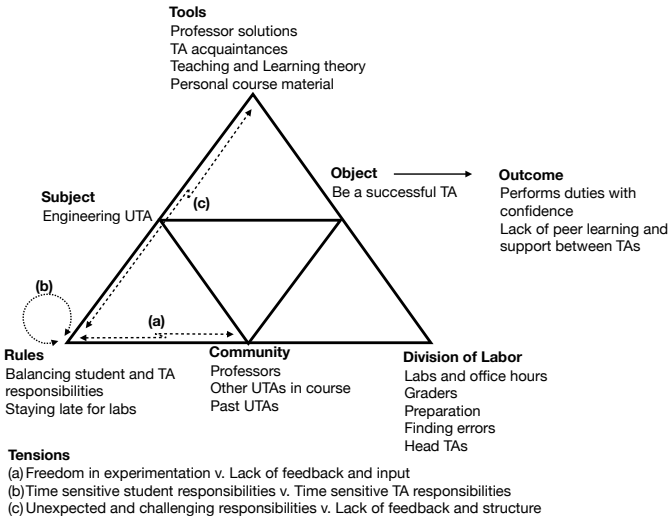

Fig. 3. Engineering UTA Activity System Diagram.

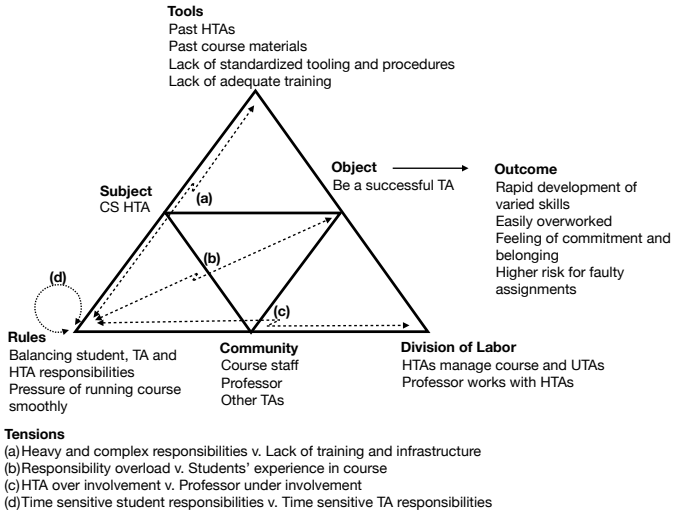

Fig. 5. Computer Science HTA Activity System Diagram.

We assumed "Be a successful UTA" as the common object in all activity systems. UTAs defined this as a teaching-based student centered activity, featuring motivations such as "facilitating student understanding," "advocating for students" and teaching in a way that suited "different learning types." "Money" and "[getting] paid" were additional reasons cited for accepting the job. "Relearning the material" and benefiting from the "clout associated with TAing," indicating an attribution of higher social status to UTAs, reveal some of the self-serving benefits of UTAing. Finally, Computer Science UTAs overwhelmingly responded that the "TA community" and wanting to be part of the "department culture" were clear motivations for applying to UTA.

1) Student-UTA Tradeoff: One tension that arose in every activity system was "Time sensitive student responsibilities v. Time sensitive UTA responsibilities." This tension resulted from a contradiction within the Tools component of each activity system. Fulfilling the role of a student while simultaneously completing responsibilities of UTAs or HTAs proved to be challenging for all the interviewees, particularly in weeks of high stress. Julia nearly considered quitting due to "[UTAing] taking up too much time." Daniel, similarly, shared a frequent dilemma he encountered as an HTA: "I have four hours and I have an assignment due and I need to release this assignment for another class. What do I do?" This moment highlights a decision that would result in harm either to Daniel's personal coursework or the course he was HTAing, which is exactly Tension (b) "Responsibility overload v. Students' experience in the course" in Fig. 5. Emma, when faced with a similar dilemma, prioritized schoolwork and described feelings of "failing" her students when she experienced weeks where she did not "have as much time to prepare going into office hours." Benjamin recounted the times when he would spend "seven hours grading on a Sunday" after he would "procrastinate grading lab reports."

The causes of such tradeoff manifesting are not immediately clear. One possibility is the elevated responsibilities faced by UTAs and HTAs across their departments. Camila mentioned

she was not "expecting that amount of responsibility" (Tension (a) "Unexpected and challenging responsibilities v. Lack of feedback and structure," Fig. 4) and, similarly, Benjamin noted that grading was "not something [he had] anticipated" (Tension (c) "Unexpected and challenging responsibilities v. Lack of feedback and structure," Fig. 3). These new and unexpected responsibilities that were not clearly communicated could have resulted in a miscalculation of expected time spent working as a UTA. This phenomenon can be compounded by students' already busy coursework and result in these moments of tension.

This tension also informs outcomes, such as "Higher risk for faulty assignments" (Fig. 5) or "Feelings of lack of preparation" (Fig. 2). Benjamin, for example, pointed to the many consecutive hours spent grading lab reports on Sundays as a decision that could adversely impact his "performance in a problem set in another course," implying he chose to prioritize his UTA work rather than his coursework. For Camila and Daniel, the two students we interviewed who served as HTAs, this tension usually arose when they were on two deadlines: one to release a specific assignment and the other to complete their own coursework. Daniel faced this dilemma by "[pushing] the release" of the assignment. Camila similarly described moments where "homeworks would come out late," in part, due to the consequences of the tradeoff described.

2) Professor Involvement: The interactions or relationships between the instructor of the course and the UTAs was a source of many tensions throughout the different activity systems. Emma pointed directly to the professor's tone and involvement in her courses as a defining factor of a positive UTA experience: "culture definitely starts with the professor." She recounted a negative episode where the instructor "[engaged] a lot with the men" while "not remembering the names of the different women [UTAs]." The same professor was not frequently seen at course staff meetings. In contrast, Emma shared an experience in another course where the professor created a much needed "positive momentum" during UTA Camp that continued on during the term. The same professor made an effort to "make themselves clearly available," which, to Emma, has been a "huge differentiating factor" in positive and negative UTA experiences.

In addition to tone setting, professors play a vital role in supporting and cultivating UTA-faculty partnerships. In holding workshops, for example, Julia and her fellow UTAs would often be left without solutions to the workshop problems, which were materials expected to be provided by the instructor of the course. After the "mid to end" of the term, Julia started relying more heavily on "past solutions," or her own knowledge having served as a UTA and taken many classes on the subject. The lack of resources extends to labs as well, where Julia had to frequently remember specific material she learned her freshman year as a student in the course since "there's no training" for any lab past the first in the term. The mismatch between agreed upon Division of Labor in the course with the tools required for Julia to engage in her job reveals Tension (a) "Required tools created by professor v. Professor not engaging in responsibilities" (Fig. 2).

Camila also describes her experiences with the level of involvement of certain professors. In her interview, she described her discomfort with writing assignments and receiving minimal input from the professor. Camila also expressed feeling "unprepared for rubric writing" and uncertainty in her ability to "assess how students are doing" in the course. In contrast to the tensions outlined in Julia's activity system, here we see a scenario where the norms or rules of how labor is divided between HTAs and professors results in feelings of unpreparedness. This contradiction between Division of Labor and Rules reveals Tension (c) "HTA over involvement v. Professor under involvement" (Fig. 5).

These anecdotes show that the presence and positive influence of a professor working with the UTAs in their course is nearly crucial to promoting success among UTAs. Additionally, the two scenarios illustrate how this presence and influence is not a guarantee across departments at Brown University, indicating a lack of a necessary support mechanism for HTAs and UTAs. All the UTAs involved in the Computer Science department pointed to the active role of prior UTAs and HTAs in filling the gap left by the professor. UTAs and HTAs often share course resources with each other and seem to be a driving force behind each other's support and development. When this HTA and UTA support network is not present, its absence is felt, as demonstrated by Benjamin's interest in collaborating with other UTAs: "it would've been interesting if I could've collaborated with the [UTAs] and got input from them."

3) Engaging in Responsibilities: HTA responsibilities are often complex and have a strong impact on student learning, warranting a close analysis on how HTAs engage with students and the tensions that relate to them. In Fig. 5, Tension (a) "Heavy and complex responsibilities v. Lack of training and infrastructure" refers to the lack of infrastructure and technical resources available that force many HTAs to resort to implementing existing grading scripts or rethink course policies every term, due to lack of knowledge and access to materials created by past course staffs. It also reveals some ways in which complex tasks such as writing assignments/rubrics and managing grades are assigned to HTAs without training or guidance. Tension (b) "Responsibility overload v. Students' experience in the course" (Fig. 5) reveals the nuanced relationship between the amount of work assigned to HTAs and their perceived success in the course. As noted when discussing the dilemma faced by many UTAs and HTAs when choosing to put work into their assignments over their work responsibilities, if the UTA or HTA chooses to prioritize their coursework, there is a chance the course they are working in might suffer. Finally, Tension (c) "HTA over involvement v. Professor under involvement" (Fig. 5) identifies the practice of assigning responsibilities traditionally assigned to professors to HTAs instead, potentially with no additional training, calling into question the fairness and equity of the Division of Labor between the different actors in a course.

The lack of support for assigned responsibilities is a theme

that emerged in Tension (a) "Unexpected and challenging responsibilities v. Lack of feedback and input" in Fig. 4 and Tension (a) "Freedom in experimentation v. Lack of feedback and structure" in Fig. 3. Both are consequences of assigned responsibilities without the necessary support and development for UTAs to engage in these responsibilities. In the case of the CS UTA activity system described in Fig. 4, the responsibilities of UTAs, which go beyond peer learning and facilitation into course development and specialized skill development, are not paired with feedback mechanisms for UTAs to learn from. In one of Emma's experiences, the course "was half taught in a [programming language] none of [the staff] knew how to use." When asked about the feedback mechanisms Emma had interacted with, she mentioned "mid semester evaluations," but acknowledged the results from these are not used by UTAs for their own growth and development but used by professors and HTAs in making hiring decisions. Tension (a) in Fig. 3 manifests in Benjamin's experience since there is a lack of a community with other UTAs in his course and department with which he would be able to experiment teaching strategies and learn from.

V. Conclusion

In this paper, we applied Cultural Historical Activity Theory and Activity Systems Analysis to a series of interviews conducted across three STEM departments. This study had the purpose of identifying the roles and responsibilities present among Undergraduate Teaching Assistants (UTAs) in these departments as well as identifying and exploring the systems that support them. Our analysis shows that there are support systems in place at the institution that benefit students' work as UTAs such as the university-wide UTA Orientation held by the institution's Center for Teaching and Learning, departmental training (such as the one held by Computer Science and Physics departments every term), and structured ways for UTAs to share knowledge and experience (UTA Camp). However the tensions revealed there are areas for improvement to support UTAs to engage in their work successfully. Additionally, our analysis shows that this gap in institutional support is occupied by peers and UTA acquaintances.

This study analyzes the experiences of an ever growing and yet understudied group of UTAs. Studies or evaluations such as these help ensure that student workers are not being overburdened by their responsibilities or duties by determining what exactly those responsibilities are. This study also reveals the incredible amount of involvement undergraduate students are now having in educating their peers: from the traditional office hours role to a position of assignment creation and policy enforcement. Due to complex skills UTAs are being asked to engage in and the heavy influence they are having over the educational experiences of students, we advise institutions to start engaging in three primary activities. The first is the periodical evaluation of their own UTA programs by gauging not only the experiences of students, but also those of the UTAs themselves. We see this study as the beginning of this evaluative process, but emphasize that the findings here should only serve as a departure point for future areas of focus rather than an evaluation itself due to the limited scope and generalizability of the interviews. In the case of Brown University, we are using results from this study to inform institutional policy regarding how to work with UTAs in the future.

Second, based on the findings of these evaluations, institutions should then adapt their existing training and support mechanisms to ensure the needs of the UTAs are being met and the goals of the UTA program are being accomplished. If initiatives such as the university-wide and departmental trainings are expanded, they could provide UTAs with high quality resources and support to engage more effectively in their work. Without these two measures, tensions, such as the ones described in this paper, could arise and proliferate while remaining unknown to the institution.

Our final recommendation is to focus on working with faculty and students to create a culture and community of student partnership [17]. This calls for incorporating UTA voice within the course development and implementation process. Several UTAs within our study were already involved with assignment design with limited faculty involvement. This created tensions regarding their preparedness to do the work they were expected to do as well as their student/UTA balance. This could be addressed by reframing UTA roles as being part of a teaching team. As was evident from the UTAs we interviewed, instructor and fellow UTA involvement was important to creating an effective teaching atmosphere. Teams such as these could give UTAs autonomy in working on aspects of the course with others who share similar interests and goals and could prevent experiences of otherness, such as those experienced by Emma as a result of her professor's gendered treatment, by creating support mechanisms and more equitable division of labor within the team itself.

Future work should be done to understand the broader experiences of UTAs across more than just the three departments. This was a limitation of the study. Approximately 750 students are hired as UTAs each term, some of which are returning UTAs. While our sample size is small compared to the total number of UTAs, we were able to gain insight into how UTAs enact and are supported in their roles. Now that key issues and points regarding the support and development of UTAs have been identified, other data collection methods can be employed, such as an institutional survey informed from this study, UTA focus groups, and observations. Additionally, the impacts of heightened student involvement in curriculum development should also be studied, as it is happening in at least one significantly large course at the university.

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