A Study of Graduate Students in an Astrophysics Bridging Year: Identifying Contradictions in a Complex System

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Abstract. Black South African students who transfer from "Historically Black Universities" to the National Graduate Program in Astrophysics and Space Science at the University of Cape Town often struggle academically. While our previous studies focused on student epistemology and went some way towards understanding student under-performance it became clear that broader socio-cultural and systemic issues were playing critical roles. Using Cultural Historical Activity Theory (CHAT) as a theoretical perspective we (a) characterized the broader context as an Activity System and (b) identified the four main types of systemic contradictions as proposed by the theory.

INTRODUCTION

Astronomy and Astrophysics are designated flagship areas of research in South Africa [1]. To this end, a national graduate structure the National Astrophysics and Space Science Program (NASSP), was established at the University of Cape Town with the aim of producing PhD graduates. Graduate study in South Africa usually involves three successive degrees: a one year coursework intensive "Honors" degree followed by a Master's degree that is completed over two or more years and comprises coursework followed by a research dissertation. Students finally proceed to the PhD degree which involves only a research dissertation.

However, after six years of operation of the NASSP, the limited success of South African black students, in particular those who transferred from "Historically Black Universities" (HBUs) [2] were of major concern, especially at the honors level. (For the present purposes HBUs refer to universities that were designated to serve specific black groupings under the previous apartheid system in South Africa).

To this end, a one year bridging program was established, the Extended Honors Program (EHP), aimed at preparing students from HBUs for the NASSP Honors degree. As part of this initiative various research projects are being undertaken with the aim of identifying and deepening our understanding of the nature of the difficulties experienced during the transition to the University of Cape Town.

PRELIMINARY STUDIES

In order to identify and understand the nature of difficulties students from HBU face in the transitions they make, we began by investigating students epistemologies. We administered the Epistemological Beliefs Assessment for Physical Sciences (EBAPS) [3] to different cohorts of the EHP students, conducted semi-formal interviews and administered identity surveys.

EBAPS provided some information about student's epistemological stance, however at a point we noted that in general, physics and astronomy Honors courses in South Africa are all traditionally delivered and examination driven, similar to the undergraduate courses. However, the Honors year also includes a small project which requires deep content understanding and scientific reasoning in order to be successful. It appeared that these two modes, surface learning and deep understanding of content, were in conflict in the Honors year. Thus even if epistemology were an issue, it did not appear to address this critical aspect. Therefore a broader framework was needed to better understand the underlying issues. The prevalence of systemic conflict and tensions within the program suggested a theoretical perspective which highlighted these issues. Hence our decision to use Cultural Historical Activity Framework (CHAT) [4,5,6].

THEORETICAL PERSPECTIVE

The main unit of analysis of activity theory is the activity system. In CHAT, an "activity" is constituted by actions; the [or these] actions are understood with reference to the broader activity system. Analyzing an activity system allows one to understand individual activity in relation to its context and how the individual's activities and the context affect one another. This helps document the historical relationships among multiple activities by identifying how the results from a past activity affect new activities. Engestrom represented the structure of an activity system as six interacting components forming an "activity triangle" as shown in Fig 1.
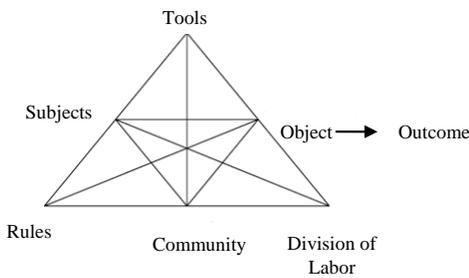

FIGURE 1. *Engestrom's representation of the structure of an activity system.*

Subjects: the individual or group of individuals involved in the activity.
Object: the common goals which subjects in the activity system are working towards.
Tools: mediate the object and consequently the outcome of the activity. The available tools and how they are used transform objects to either an intended or unintended outcome.
Community: participants of an activity system who share the same outcome.
Division of labor: division of tasks and roles among members of the community and the division of power and status
Rules: formal and informal rules, norms and traditions that regulate actions and interactions within the system.

Principles of CHAT

Engestrom formulated five principles of activity theory. The first is that the main unit of analysis is the activity system. The second principle is the *multivoicedness* of the activity system. An activity system is always a community of multiple points of view, traditions and interests. The third principle of *historicity* argues that the history of activity systems helps understand their problems as well as their potentials because "parts of older phases of activities often stay embedded in them as they develop [7]." Historicity explains where we have come from and how that impacts the system in study. The fourth principle of activity theory is the central role of *contradictions*. These are dilemmas, disturbances, and discoordinations internal to human activity that play a role in the activity system [8]. Since activities are open and dynamic systems, when an activity adopts a new element from outside, for example a new technology, a new rule in the classroom, or a new object, it often leads to tensions. Contradictions generate disturbances and conflicts but also cause innovative attempts to change the activity. Four types of contradictions in activity systems have been identified [6] (see Table 1). These classes are not hierarchical and can be interlinked depending on the focus and description of the studying system (see Fig. 2). It should be noted however that the representation in Fig. 2 is not a static model but a macro reflection of the system. It has a history, nested instances of activity, which when viewed from different vantage points and from different points in time, may be construed and represented differently [5]. The fifth principle is the possibility of *expansive transformations* in activity systems. This principle proposes that through the resolution of contradictions, a system can develop and transform into a better version of itself.

TABLE 1. Engestrom's four types of contradictions in an activity system.

Primary Contradiction	Occurs within each constituent component of the central activity e.g. within the objects
Secondary Contradiction	Appears between the constituents of the central activity e.g. between the objects and the rules
Tertiary Contradiction	Occurs when activity participants face conflicting situations by adopting what is believed to be a newly advanced method for achieving the object
Quaternary Contradiction	When activity participants encounter changes to an activity that result in creating conflicts with adjacent activities

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DATA AND METHODOLOGY

In this study we employed the principle of contradiction in CHAT to understand the nature of difficulties the EHP students face in the transitions they are making. There are two main stages involved: the first is to *describe the system* (see Fig. 2); the second is to use the description to *identify the contradictions* in the system.

We report on data collected through semi-formal interviews with the EHP students. Two independent researchers watched the videos several times. We noted and marked the episodes that indicated that a contradiction was present. When episodes indicating a contradiction are identified they are transcribed and analysed for categorization.
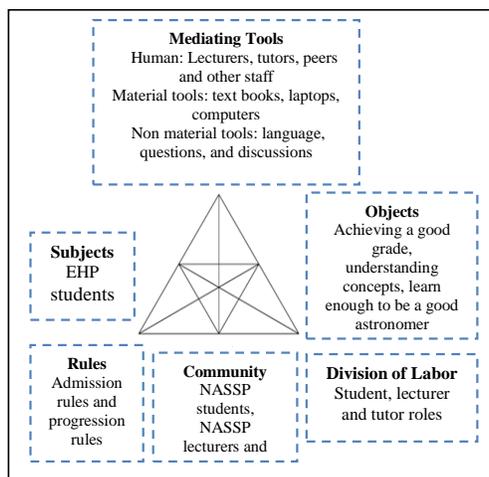

Figure 2. *Structure of the studying (NASSP) activity system.*

FINDINGS: CONTRADICTIONS IN THE SYSTEM

We show some illustrative examples of the four types of contradictions in the system. In each section a student quote is selected to represent the tension or contradiction. An illustrative quote is provided first, followed by discussion.

Primary Contradictions: Tension Between Grades and Personal Sense-Making

Student: *Yeah...like he had ways of solving a problem where we had to create bins and I didn't understand his method so I used my own method, it was a bit longer than his but then it worked*

(giggles)...you know...and like.. I could follow it step by step and understand what is going on, and then when he marked the paper, he said that...it's good but then...(Shaking head) not that it is good- he marked it correct but then he said that it's a poor method. So now you are stuck with the problem of...ok I understand this, I don't understand his method and I am going to write the exam. So if he asks me the question, what is he going to mark like...is he gonna still give me mark or is he gonna reduce because he wanted it his way, so it's like very stressful sometimes...

We see a tension here between personal sense-making and the student's grades. The personal sense-making is also influenced by an authority figure. Two interpretations are that personal understanding leads to fulfilment and understanding but it might have a catastrophic effect if it also leads to a poor grade. The NASSP community values personal ownership and understanding, but the "gate keeper" that allows one continuous access to the community is a mark or grade which, more often than not, forces students to use other strategies such as rote learning and memorization, which do not aid understanding or personal ownership.

Secondary Contradictions: Tension Between Students' Understanding and Lecturer Status

Student: *The main problem with the NASSP is that...I don't know...they were trying to take every ummmh...most of our lecturers, they were like...people with high positions...you know like (hands high in the air)...yeah. I mean you can be...you can be in those high positions, top astronomer, but it doesn't necessarily mean that you are...you are a good lecturer or something like that...yeah...*

This highlights a tension when the "object" is teaching. UCT is a research-led university and there is a strong feeling that lecturers must be active researchers, as this enhances the teaching. However students generally think it is best that teaching is done by those who are skilled educators.

Tertiary Contradictions: Adopting New Attitudes and Beliefs about Learning ("Epistemological Tensions")

Student: ok...ummh when I came here like...it's like in my mind I thought maybe we are only going to do research, I thought we are not going to attend classes, something like that you see...that is why maybe when

we are taught I always wanted to understand everything, I wanted to like, if they are teaching something, I just want to go in depth...like I don't know.... I thought maybe is...is going to be something different so on that part I was left behind, so maybe that is why I have struggled sometimes...that is where maybe I missed the point...

Tensions were created by the expectations the EHP students had about the method of learning at UCT. The students imagined that learning at UCT would be very different from the styles they adopted as undergraduates at HBU's where the students usually knew what the instructor wanted and could follow a set path to achieve the object and get a good grade. However, this is not strictly the case due to the conflicting value system observed in the Honors year at UCT. However this tension, unlike the primary tension is as a result of students' personal beliefs about the UCT NASSP Honors year and not as a result of the NASSP system itself.

Quaternary Contradictions ("Historical Disturbances")

Student*: It's quite a pressure because some...sometimes you just wanna close yourself off the the family for a while and then you come back and say ok cos...like I graduated and I told them and then I told them it's fine I will be able to fund myself, but there are still stuff I still need from home, so it becomes a problem. Like...asking for finances...and then saying...hearing them saying they are struggling its quite difficult knowing that you have a degree and you could do something to help them but you can't because you know that in order...if you go out, you still need to come back and study again in order for you to get a promotion or...stuff at work. So it becomes a...when you are dealing with family it becomes difficult.*

The expectation of family and friends for most of these students is for them to get a job and help the family financially after the first degree. When these students decided instead to pursue degrees in astronomy it creates a *quaternary tension* of family pressures.

SUMMARY AND DISCUSSION

While it is not possible to discuss this in detail, we also looked into a subsystem involving an intermediate level electromagnetism course to detect "micro and macro" tensions. Both historical and systemic tensions were noted to create disturbances such as poor conceptualization of physical problems, mismatches in students' and lecturers' expectations and unproductive learning strategies.

The CHAT perspective was useful in highlighting contradictions present in the NASSP activity system. It also helped in understanding student and lecturer experiences and more importantly highlighting areas where improvements might be necessary. One of the positive features of CHAT is that it does not apportion blame but rather seeks to identify the different ways in which objects are viewed so that the sources of issues arise in the interactions of these perspectives. While the present work is limited to identifying and describing the system and its problem areas, CHAT also offers a way forward via the so-called expansive learning cycle in which contradictions are viewed as opportunities for new learning experiences. In summary, CHAT appears to hold much promise as a perspective that could be usefully employed within the PER community as a way of dealing more holistically with the large range of issues that are often compartmentalized.

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