

Examining Black Diaspora Participation in Engineering using Narrative Inquiry

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Abstract

This paper examines the use of quantitative research agendas on systems modeling to study anticipatory cognition and cultural competency. This combination results in an integrative science approach to explore the intersectionality of metacognition, academic self-efficacy, stereotype threat, scholarly reasoning and identity among minority black diaspora graduate students. Extant literature focuses on social support models, but the novelty of the approach in this paper examines metacognition in action within a culturally-aware context. Data were collected as semi-structured narrative inquiry to capture metacognition during learning using narrative identity construction as a tool.

There was a total of five students in the study including three females and two male participants in their first year of the graduate studies. However, the analysis focused on three of the participants who provided data consistently for eleven months – two males and one female. The participants provided data including responses to Likert scale questions, and weekly video narratives in response to three sets of questions each week in an *n-of-1* big data approach. This approach has the empirical benefit of allowing more inclusive and personalized analyses to draw conclusions. By observing the requirements of an approved IRB protocol, the analysis based on the transcripts of the video recordings, and the examination of change within each individual over time was confidential and conducted with de-identified data. Video recordings are coded and analyzed using HyperRESEARCH™ version 3.7.5.

The result calibrates students' comprehension, integration, and application of impactful, data-driven research skills. The metacognitive development portion examines the influence and dynamics of anticipatory cognition, stereotype threat, identity, and academic self-efficacy as the students' progress through the process of quantitative skills mastery. This paper reports on the highlights of the distilled data on: (i) *anticipatory cognition* – construct to describe use of prospective memory to simulate future associations and expected outcomes; (ii) *academic self-efficacy* – captures the perceived level of confidence in the participants to engage successfully in specific cognitive acts associated with academic mastery; (iii) *stereotype threat* – captures the anxiety associated with the salience of status as a member of a group that is stereotyped as underperforming in a specific area; (iv) *identity or categorization* of the self as a scholar and engineer. Other themes emerging include perseverance or determination, isolation, extant knowledge, future anticipation, and problem solution focus.

1. Introduction

It is well-established that there is a serious dearth of doctoral scholars of color, particularly Black or African Americans, in the STEM fields, particularly engineering. This problem is exacerbated by the paucity of these students in the pipeline both in the hierarchy of the engineering academy and *en route* the engineering professoriate. Thus, the necessity of finding valid and culturally competent methods to develop engineering modeling skills [1] among Black or African American doctoral students is a justification for this research. Much of this reasoning is explicit in [2], who present eye-opening examples of how quantitative and computational modeling of big data is fraught with biases that perpetuate and even increase inequity across the nation. In the work, *Weapons of Math Destruction*, inadequate understanding of analytics and other quantitative cognitive acts have irreversible negative impacts [3].

Therefore, an approach to addressing this problem stems from the need to understand how doctoral scholars of color are able to integrate cultural identity and self-efficacy [4–7] in contexts where stereotype threat might be prevalent, such as higher education, STEM programs, and intensive research labs. This paper aims to identify, understand, and describe the interplay between the sense of identity, self-efficacy, metacognition of modeling formalisms, and stereotype threat with a particular focus on black diaspora students. By employing (i) a discovery approach that elicits the thought processes and the evolution over time of the narrative identities of scholars of color, and (ii) uncovering a process of coaching scholars of color in a supportive academic, this paper sheds light on some of the underlying inhibitors to the success of underrepresented minorities in engineering [8–11]. Understanding these limitations informs the strategies for a collaborative approach to the development of highly skilled and competitive graduate scholars.

By extension, these strategies offer promises of strengthening institutional capacities across all institutions, including the two institutions partnering in this collaboration – a Historically Black College/University (HBCU) and a private Predominantly White Institution (PWI). The environment for this exploration targets a curriculum that aggregates cognitive science, technology management and mathematics into strategies that improve students' learning. In line with NSF's R&RA programs, this research uses a full immersion of the students into engineering modeling to evaluate different adaptive learning formalisms with the application of mathematical models for problem solving in engineering. Premised on anticipatory cognition to influence students' reasoning about the problem content [12], performance and social learning variables such as stereotype threats [13–15], identity [16], and engineering modeling self-efficacy [17–19] are evaluated.

2. Program Elements

The program is conducted across two institutions with a total of three black diaspora graduate students in the process of model development, reflection and narrative inquiry. These elements and the participant recruitment process are detailed in the following sections.

2.1 Model Development

The research strategy is to generate an integrated framework that evaluates the role of anticipatory

cognition in the research tasks that the students conduct. In other words, while the students focus on the research topics for their dissertation, data on their reflections through narrative enquiry are collected. For example, the students address modeling efforts related to how technology investment decisions are determined in the face of uncertainties. Premised on the notion that complex adaptive human-technology systems evolve with a changing environment [19, 20], the research context the students are exposed to focuses on how policy influences technology investment decisions and vice-versa. The cognitive connection is how the students are able to co-evolve their ability to mentally connect prior investment outcomes with future goals or policies towards some of the sustainable development goals [22]. Specifically, the improvement of return on investment is a goal that addresses the question of how to incorporate anticipatory cognition into the decision-making framework. For example, a modeling platform is the computable intervention approach for improved future technology scenarios. This approach accords the students the exposure to the fundamentals of probability and decision theory in the design of exploratory models to improve the value of decisions across technology boundaries, improve human judgments in the context of future uncertainties, and better adapt new technology to be flexible enough to make use of limited investment resources from an opportunistic basis. This model development process aims to equip the cohort with empirical and analytical capabilities, mathematical optimization modeling, and decision-making analysis under uncertainty.

2.2 Reflection and Narrative Inquiry

A narrative inquiry process is implemented to capture scholars' reflections. This process uses an integrative science approach to explore the intersectionality of metacognition, academic self-efficacy, stereotype threat, scholarly reasoning and identity among black diaspora graduate students. The extant literature focuses on social support models with a limited examination of how metacognition – captured in this research in a just-in-time manner – during learning. The absence of a focus on anticipatory cognition and the process of knowledge acquisition in engineering tend to ignore adaptive learning formalisms that underline how ethnicity and other social stratifiers influence the way black diaspora graduate students approach and process engineering models. Thus, identifying a conceptual model for a social learning experience similar to Vygotsky's "Zone of Proximal Development" (ZPD) [23] is critical to enhancing the mentoring of these group of scholars. In sum, the inclusion of socio-cognitive elements with the promise of broadening participation in engineering particularly on energy technology policy and its influence on technology investment decision making magnifies the interdisciplinary aspect of solutions that real world problems require.

3. Methodology

The methodology employs carbon and energy technology policy modeling with an interdisciplinary lens. The participants provided data as "participant observers" of their own learning process by using reflection and narrative inquiry such as their responses to Likert scale questions, and weekly video narratives in response to three sets of questions each week in an *n-of-1* big data approach. This approach has the empirical benefit of allowing more inclusive and personalized analyses to draw conclusions. With the aid of a mixed methods quasi-experimental comparison study, we used the "site" as the primary independent variable (institutions A and B). The *n-of-1* approach emphasizes, rather than collecting small amounts of data on a large sample,

the collection a large amount of data on a small sample. Prior errors made in traditional quantitative human subject research has led to the *n-of-1* movement. The effort focuses on examining each person as a unique source of a large volume of observations [24–26] and using a combination of small sample statistics and big data modeling approaches to explore and describe phenomena of interest. We interpret findings in the context of the lived experience of each participant, and generalizations are made only in terms of patterns that repeat across more than one person. Data aggregation and analysis methods include averaging within-subjects analysis (participant across time) and not between-subjects analysis (participants compared to each other). The quantitative knowledge domain is adapting a phenomenological perspective that is known in the qualitative research domain. Table 1 below summarizes the constructs and methods used to elicit the variables and parameters to model each students’ progression.

Table 1. Summary and schedule of data collection over the 11-month period

Construct	Instrument	Data Structuring	Elicitation Schedule
Anticipatory Cognition	Video: 10-minute guided narrative reflections on learning after informal learning research sessions	<i>Qualitative:</i> Verbal themes from axial coding. <i>Quantitative:</i> Quantization of themes for modeling.	Once per week
Academic Self-Efficacy	Modified Engineering Modeling Self-Efficacy Questionnaire	Quantitative: Self-report ratings/Psychometric	Two times per month
Stereotype Threat	Video: 10-minute guided narrative reflections on learning after informal learning research sessions	<i>Qualitative:</i> Verbal themes from axial coding. <i>Quantitative:</i> Quantization of themes for modeling.	Once per week
Identity	Video: 10-minute guided narrative reflections on learning after informal learning research sessions	<i>Qualitative:</i> Verbal themes from axial coding. <i>Quantitative:</i> Quantization of themes for modeling.	Once per week
Emerging Constructs	Grounded Theory Coding	<i>Qualitative:</i> Verbal themes from axial coding. <i>Quantitative:</i> Quantization of themes for modeling.	Weekly as data are collected and coded

The construct definitions in Table 1 are as follows:

1. **Anticipatory Cognition:** Construct to describe use of prospective memory to simulate future associations and expected outcomes [27, 28]. Operationalization: Descriptions of expectations and outcomes of activities requiring application of quantitative skills and knowledge.
2. **Academic Self-efficacy:** Describes the perceived level of confidence in learners to engage successfully in specific cognitive acts associated with academic mastery. Operationalization: Ratings on the Engineering Modeling Self-efficacy Scale [29].
3. **Stereotype Threat:** Anxiety and heightened mental workload associated with salience of status as a member of a group that is stereotyped as underperforming in a specific area.

Operationalization: Affirmations related to inferiority, loss of motivation, expressions of anxiety about stereotypes, and fixed mindset regarding mastery [30].

4. **Identity:** Categorization of the self as a scholar and engineer. Operationalization: Self-referencing adjectives describing a quantitative scholar persona and sense of belonging to communities of practice; language of identity construction/deconstruction around data analytics, modeling, and engineering [31].
5. **Emerging Constructions:** Patterned constructs that emerge from intersectionality of the constructs 1 – 4 and/or other new constructs.

4. Participant Recruitment

Three black graduate students participated in this study – two at one collaborative partner institution and one at the other. The students were selected from the pool of qualified applicants for doctoral studies at the two institutions. The students identified as black diaspora from Jamaica, Nigeria, and Sudan. This distinction is crucial because the identities of the participants may be influential not only in their experiences but also in the outcomes of the data analysis. The students have backgrounds ranging from prior degrees in environmental law and legislation, renewable energy research to general STEM expertise. Two of the students at one site started their doctoral degree studies in January 2017 while the third at the other site started in September 2016. The students are made up of one female and two males and are between the ages of 25 and 40. Two of the participants are in the graduate program at a private predominantly white institution in the northeast region of the U.S. and one participant is in a graduate program at one HBCU. The number of students at both institutions reflect the amount of funding provided by the Broadening Participation in Engineering (BPE) program of the National Science Foundation. The funding supports the students as Graduate Assistants during their studies, and it is the funding that underlines the incentive for their participation in the study. This research was reviewed and approved by the Institutional Review Board at both institutions.

5. Data Collection and Analysis

Participants record weekly video responses that are captured with the aid of a provided recording device and on their individual smart phones. The responses are then uploaded in a secure, password-protected location for transcription.

5.1 Data Collection

Students in this study are considered “participant-observers” and have been asked to narrate their learning process via reflection and narrative inquiry. Each participant was given a set of guided questions for narrative identity elicitation that document their learning process. Questions fall under three main headings: anticipatory cognition, stereotype threat, and scholarly identity. There are two questions in the anticipatory cognition section, and three questions in both the stereotype threat and scholarly identity sections that participants must answer. At the end of each week, the participants are required to sit down in a quiet place and video record their answers to the questions. One main section (with the subsequent questions) is recorded on one video at a time. At the beginning of each video, the participant specifies the date, and which set of questions is being answered at the time. Upon completion of their answer (approximately 10 minutes), the participant

concludes the video recording for that session. The participant then moves on to the next set of questions by starting a new video and identifying the next set of questions that are being addressed in the video. At the end of each week, participants submit three videos approximately 10 minutes in length that address each set of questions from the three main sections. Once the videos have been recorded, they are uploaded to Dropbox, an online digital data sharing site. Each participant has been assigned a folder on Dropbox where they can upload their files. An external data collector has also been given access to the folders on Dropbox and removes the files from Dropbox and saves them to a secure external hard drive. Data included in this study were collected between February 2018 and December 2018, a period of eleven months.

5.2 Data analysis

Each week, the external data collector viewed and transcribed the video recordings from the participants. The transcriptions are de-identified to maintain confidentiality. The transcriptions are then sent to two undergraduate students for coding. The undergraduate students were trained on the data coding process with a sample data set prior to coding the transcriptions for this project. The undergraduate students code each transcript individually and their coded results are given to the external data collector. The external data collector reviews the coded transcripts and compares the coding patterns between the two undergraduate students. In practice, the external data collector reviews a portion of a transcript from a participant and looks at which code if any is applied by the undergraduate students to that portion of the narrative. If the two undergraduate students and the external data collector agree on the code given to the portion of the narrative, the code is applied. If the two undergraduate students are not in agreement on the code given to a portion of a transcript, the external data collector serves in the role of tie-breaker and either decides which of the two codes should apply or assigns an entirely different code. In addition to the five constructs described in Table 1, six additional codes emerged:

- Perseverance/Determination- derived from narratives that speak to participants' continuing in school, class, and their research project despite encountering obstacles.
- Isolation/Loneliness (Academic Disconnect) - derived from narratives that speak to participants' difficulties with family and friends lack of understanding about what it is they are doing and/or having the time to talk to or associate with family and friends.
- Extant Knowledge-derived from narratives that speak to participants' discussions about things they knew prior to joining this research study that may help them with their research project/dissertations.
- New Information-derived from narratives that speak to what the participants have learned in various courses each week.
- Future Anticipation (academic "to-do") - derived from narratives that speak to plans the participants make for improvement during this process or narratives that regard what they think will happen as they progress in their respective programs.
- Problem-Solution Focus-derived from narratives that identify problems the participants may have encountered thus far and their plans to address or correct those problems.

Once all data has been manually coded, all codes and data were entered into Microsoft Excel and HyperRESEARCHTM version 3.7.5. for further analysis. The analysis includes frequency of observations over time and a correlation evaluation with test of statistical significance.

6. Results

A thematic analysis was conducted on the data collected between February and December 2018 – a period of eleven months. First, based on the coded transcripts, Figure 1 shows the summary of the frequency for each construct over the duration of continuous data collection. In this figure, the dominance of Anticipatory Cognition, Academic Self Efficacy, Stereotype Threat and Identity is significant. While Anticipatory Cognition and Academic Self Efficacy appear to show declining trends over time, it is evident that the issues of Identity and Stereotype Threat barely changed. The decline in Future Anticipation and New Information are correlated with the marginal changes in their Anticipatory Cognition or their academic awareness.

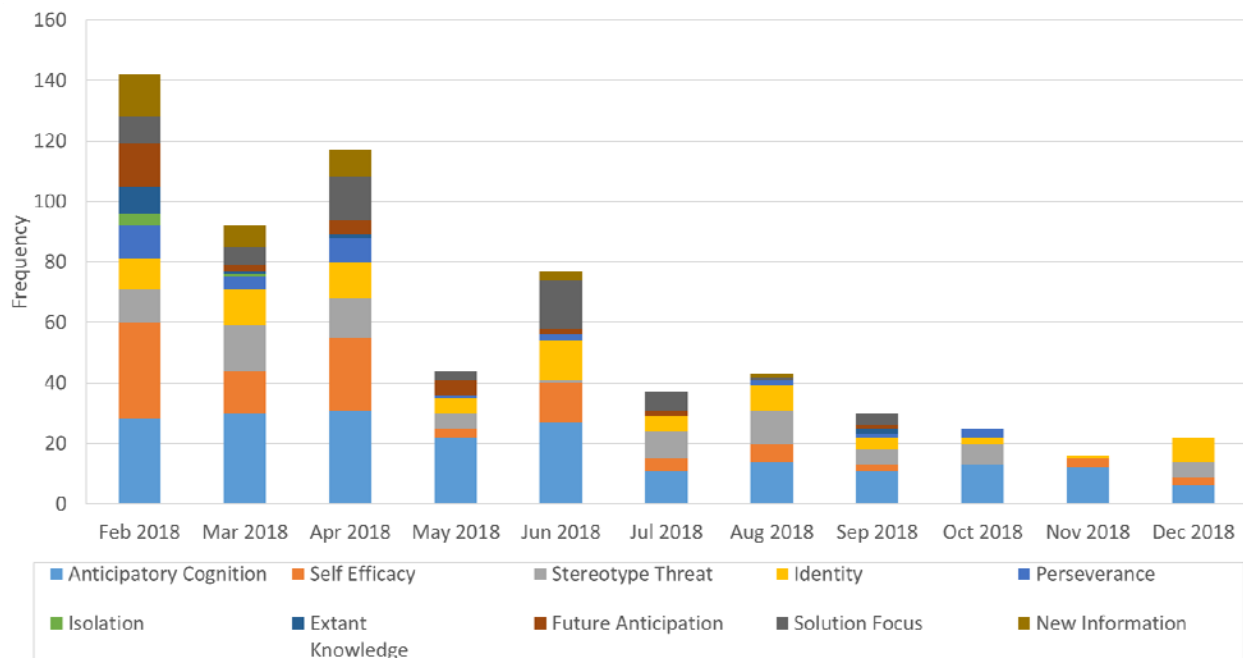


Figure 1. Summary frequency count of constructs

In the following subsections, we discuss the results along the themes described both in Table 1, section 5.2, and Figure 1. In some of the quotes following the constructs, the students tend to identify themselves as African American when in reality they are black diaspora students in Engineering.

6.1 Anticipatory cognition

The anticipatory cognition theme was applied to responses that described the use of prospective memory to simulate future associations and expected outcomes. Typical responses to the questions in this section included issues surrounding learning new material in an unfamiliar discipline, choosing a research topic, selecting an appropriate methodology, and experiencing unexpected challenges from courses and/or research project development. For example, one participant spoke about choosing a research topic

“...I know that in the past that that was a big challenge to figure out right topic you choose

to conduct your research but advisor consultation we reach to a point where I consider it is a concrete base for kicking off my research project....(February, 2018)''.

Another participant stated,

“Another challenge is I need um, I still haven’t narrowed down, the specific...plan for myself and we are going to project now but I’m not sure that is what I will eventually do in the next for years so I still, I’m still, I believing I’m getting closer to it, I know what exactly, I know the area I want to go into. I just need to find the gap in that area and dig into it and exploit it... (March, 2018)”

As data collection continued, over time, participants’ responses to the anticipatory cognition questions shifted focus from topic selection and problems that were hindrances for getting started with their research projects to problems they did not anticipate with the actual implementation of their research, specifically about writing and data collection. For example, one participant stated,

“The main challenges, at this time, (long pause) lit review, literature review, designing, the appropriate instruments and administering that. That is the plan for the summer, which is upon us (June, 2018.)”

Another participant noted,

“...okay looking at this specific project that I’m working on, well I never knew it would be a challenge for me to get this kind of data. I thought that challenge was going to be on how I actually wanted to represent that data and the tools I want to use and how I want to actually represent the data graphically alongside the technology across different states. But now the challenge seems to be how to get the data that I need, I know what I want to use it for. I know how I want to represent it. But the main challenge now is actually getting what I need... (July, 2018).”

6.2 Academic self-efficacy

Academic self-efficacy describes the perceived level of confidence in learners to engage successfully in specific cognitive acts associated with academic mastery. Participants typically described their abilities and capabilities based on things they had accomplished during the current week of video recording or on feedback they received from course professors or academic/research advisors. In the early video recordings, participants spoke more about academic self-efficacy they felt based on what was occurring in their courses:

“I had a presentation. I had a presentation and um it went well, it went better than I thought it would. I thought it was...there was a time when I thought it was going to be a disaster (chuckles) but um it went better than I thought. Um I got um good feedback...good feedback from the instructor. Good feedback from the instructor and it was quite interesting and um she even commented that I seemed to go further than what she wanted which maybe that is a good thing (February, 2018).”

“...okay for my engineering economics class I got most of my grades for my assignment, about four of them and it was great satisfying for me for getting full on all of them, all my four assignments which is good, which is a good starting point, so that has been extremely satisfying for me but it is just a starting point (March, 2018).”

As time progressed and the participants delved deeper into their research projects, more of their academic self-efficacy responses were focused on what they were able to accomplish in terms of their writing and technical research skills and their capabilities for conducting research:

“...yes, I’ve learned a lot of new things in respect to my research work um so I can say I’ve made a, a lot of progress in a way of learning so specifically I’ve uh I’ve improved with my data analysis data analysis skills in Excel and using this data uh I can... I’ve improved in that I’ve also improved in my general writing and presenting my arguments umm compared to where I started on my research (inaudible word) and where I started on this particular project I can, personally I can see improvements in my in my, in my writing and in presentation skills how I present my arguments how I present my talks on my literature so I believe I’ve made progress in that area... (May, 2018).”

“So I am really comfortable with where that is at. I am comfortable that my research skills have improved my critique and to give constructive criticism, not just to myself but my peers and peer review is an integral part of academia. So yea, I am pretty satisfied about that and I am excited about moving forward with that will have come in months in the summer (May, 2018).”

6.3 Stereotype threat

Stereotype threat includes the anxiety and heightened mental workload associated with the salience of status as a member of a group that is stereotyped as underperforming in a specific area. In most instances, participants shared problems that they felt hindered their progress both in the classroom and in their independent research efforts.

“Just reading. It’s just the reading. Read until your eyes bleed. Some of the reading does get technical and for me that will take more time to absorb. I might have to do some research as in background research to understand the content of particular articles. So, that really is the biggest challenge (March, 2018).”

“So I’m really teaching myself a lot of energy related stuff a lot of engineering which really doesn’t have anything to do with my research skills. It’s just that you have to develop a certain amount of skills in that area before even getting to the point of calling yourself an expert. So that is one of the challenges that I have (March, 2018).”

“So that’s what I learned about my accomplishments that if we keep pressing we will get results both from the class assignment and (inaudible words) being able to put my abstract and get some feedback on it cause it has been a big burden (April, 2018).”

"And I have a specific time frame, I have a special time frame that I've agreed on tomorrow, I've got to make advice when to deliver the results that I need with that data. So, it's a setback for me and it's kind of slowing things down a bit for me. I have um, I've looked at many websites, I've looked at um different articles. I'm seeing some of them state by states, which will be very difficult for me to bring all together. I'm not seeing what exactly I need in one piece, what exactly what I need in one piece (July, 2018)."

On some occasions participants did mention their beliefs on how race factored into the problems they were encountering:

"Mastering, mastering knowledge the skills, the things that I'm learning to find time management doesn't change much with race. Uh Knowledge of the subject material doesn't change much either um knowing your audience doesn't change much. Conducting research doesn't change. What I need to break down really is access to resources. That can make or break anyone it's just that that's the truth as African Americans we have less access to resources and that determines how well you can focus on doing your work (March, 2018)."

"Uh as an African American like any other student by practicing make it easy for me or anybody else to master the skill and knowledge. So by uh no practice so that is make it difficult. So the easiest way to master the skill and knowledge uh practice it. So easy can master um easy can master the skill and knowledge for this project or another project (April, 2018)."

"...but I don't think in a course like this that it makes a big difference because we all bring our various experiences to the table whether we worked or not we constantly have to call upon our experiences outside of the classroom and often times before entering the faculty so in this case it doesn't it doesn't have a great or significant impact because race doesn't (April, 2018)."

"Okay like I've said in the past I don't believe the color of your skin should um make it difficult or easy to master the skill in a subject like engineering. But then that's an ideal situation. Um we know that in reality that's not so. It's not so in reality. Um looking at my background and where I'm coming from well it could be a bit...it could be a bit challenging especially the research work and in the areas of developing my software and my soft skills. I believe they go hand in hand. That could be a bit challenging. Probably as an African American those are the areas where I need to go a bit deeper. Those are the areas where I need to work harder. Those are the areas where I need to bridge the gap basically. So um well the positive I can always take out of it, being an African American, being from a disadvantaged background has always made me want to achieve the best. Has always made me want to work harder at whatever I do. So based on that, well, that's a positive. That's something I believe that could spawn me into achieving bigger and greater goals. So um I believe I probably need to work twice as hard. Yes. And I would need to work twice as hard. If I have to work twice as hard to get these results (February, 2018)."

6.4 Identity

The identity theme includes commentary that shows how the participants categorize themselves as a scholar and/or engineer.

“What I’ve learned from that is that I can take risks I am a risk-taker and uh even though it’s more work it’s what I came for I came to learn and he really pretty much made a point (inaudible words) discussion that you know this is what a PhD program is all about you’re way to marry everything (March, 2018).”

“...oh it’s too challenging uh I try to do that on a daily basis but uh like I always see, I believe um with the time we get uh they take me for who I am and accept me for I am, and understand what I am doing, understand what I intent to achieve, understand what my goals are, understand like sits not like it is I know there are other things I can do in my life but I decide (inaudible words), but um but um they just believe in time but um but one day the fruits of the, like the fruits that are coming out of probably will get a understanding of the this is what I am doing, this is what I am spending my time in (March, 2018).”

As the participants progressed through the project, their view of themselves as a scholar and/or engineer became more specific and refined:

“...it means that I am learning about myself. That I am not one dimensional I have other abilities and I have other talents and I can reach the answers effectively as my legal skills and at the end I hope to bring them all together in a seamless match that just wasn’t thought of before (May, 2018).”

“I’m making progress a lot things now clearer, grey areas become much clearer, a lot of um questions I had a lot of unanswered questions. I had. I have answers to them now. There’s more clarity and more self-identity on what I am trying to do, and what I’m trying to achieve (May, 2018).”

“...specifically, on the micro um grade project, research project that I have been working on the data collection process. Ok what I can has been satisfying, I’ve made quite a bit of contact I’ve made a few contacts, I’ve made a few contacts I’m not going to say, not too many contacts, I’ve successfully made and they are promising leads, which I believe will materialize into tangible information (August, 2018).”

In addition, the identity focused questions asked that participants describe how they explain themselves to their families:

“I will explain myself to my family as a scholar especially to my kids and how the education can frame or change people’s life and that can be reflected in their action and their lifestyle (Feb, 2018).”

“...my work is quite time consuming so um it’s been a bit difficult having to explain to them why I cannot return their calls every single time they call why I cannot reply chat messages at every single time when they send me chat messages why I cannot reply at that exact time. So um I’m still finding my routine here. It’s kind of maybe challenging to explain myself to my family that this is what I do this is why I’m unavailable for a couple of hours. This is why I cannot spend as much time on the phone probably like I used to do a while ago. So it’s been challenging explaining myself to them. But gradually I think um I think I would be able to. Uh it will make more sense to them. It will make more sense probably understand my routine better (Feb, 2018).”

“I believe that my family has begun, begun to come around they have begun to, well to some extent they understand what what I am doing. They understand what I am trying to achieve in my PhD program. And un during this short vacation time period I’ve had the opportunities to relate one on one with a lot of my close family and friend and um I can say it’s quite an opportunity to bond, quite an opportunity to fully um explain to them how my PHD program has been going. Fully explain to them even the challenges I’ve faced during, the challenges I’ve faced because of the program, because of my research work and because of my course work, because of my interactions with faculty and staff. So, I’ve been able to sort of bring them into my world (August, 2018).”

6.5 Perseverance

The perseverance/determination theme was derived from narratives that speak to participants’ continuing in school, class, and their research project despite encountering obstacles. It also includes thoughts the participants may have shared that provided insight as to how they are processing or implementing the information they have learned.

Early in the project, their commentary centered on their ability or capability to get through the first semester and the first trials of a PhD program:

“I’m not gonna run away. I’m gonna get bold. I’m gonna get stronger as the days go by. It’s like a marathon ya know? It’s not a sprint. (February, 2018).”

“But it’s important to be in this solid sense of individuality and your own perspective that I am running my own race and nobody can run it for me. But it’s kind of useless to be peeping over another person. It’s not that kind of competitiveness (March, 2018).”

“...um if I continue to put in effort and I continue to umm focus on my work and um (deep breath) and umm focus on my work try to make us of the resources available I can actually achieve um great results I can actually continue to make progress, steady progress steady progress (April, 2018).”

As time progressed, the participants’ commentary under this theme emphasized more of their capabilities on their respective research projects:

“Well, the only way to really address doing research is to do it. It’s to just keep hammering at it like a wall and that’s kind of how I feel. That’s how the process been going, just lots of repetition. But often times, searching for the same thing on different platforms, different databases, you’ll get different results and uh (long pause) that is what drags the process really, the repetition (June, 2018).”

“Well based on the accomplishments I’ve made this week, I um well what I’ve learned so what I’ve been actually nothing is actually too hard to accomplish yet they can seem daunting, they can seem complex, they could seem very very challenging, but with determination and um with determination and with hard work with constant pressure, with constant mole seeking and constant asking questions and basically not giving up, you eventually find a way out, and once you find a way out of it, it’s getting better and better and um the funny thing is it doesn’t always look as complex as it used to doesn’t really complex as it initially set out to (June, 2018).”

6.6 Isolation (academic disconnect)

The isolation/loneliness theme was derived from narratives that speak to participants’ difficulties with family and friends lack of understanding about what it is they are doing and/or having the time to talk to or associate with family and friends. In general, participants who spoke about isolation and loneliness were referring to their feelings of being alone in that they were the only person among their friends and families seeking a PhD:

“Sometimes I feel as if I’m just on my own, in my own world doing this thing...um I just can’t break it down to them (February, 2018).”

“For friends, those of them that understand, yes though a lot of people just look like oh why he’s going for a PhD, oh why he loves um books too much like (inaudible words) oh he’s a nerd and things like that. Well I know it’s beyond that; it’s beyond that. Its um...it’s beyond that (February, 2018).”

“You’re diving deep but kind of feel alone in a sense (March, 2018).”

It should be noted that this theme seemed to manifest early in the participants’ progress in their respective programs and was not seen in the latter months of data collection.

6.7 Extant knowledge

Extant knowledge refers to narratives that speak to participants’ discussions about things they knew prior to joining this project that may have helped them with their courses and research project/dissertations. Often participants referred to knowledge they had accumulated over their lifetime, specifically knowledge obtained while seeking previous degrees:

“Maybe my engineering background could um make that easy. Maybe it could um make, make um gliding through those, those technical rated areas. Maybe it could make it easier I believe so. Yeah. But sometimes I think um it could even be a disadvantage

because sometimes as engineers we ...we...it's kind of um...it could be a negative for us if we keep sticking to it this the way we do it this the way we think as engineers and all (February, 2018)."

"...but it's the same organizational behavior that I have studied in my psychology degree but with a more focus on technical organizations which I enjoy which I am interested in because I have a very strong interest in business and spent three years in banking and did a lot of commercial law so I can quickly bring those aspects of my life to bear on the subject matter and its relevance... (February, 2018)."

"I wouldn't have don't well I didn't think that before coming here that reading faster or just being able to read quickly would be an issue. Because I mean, I've gone to law school and law schools to be exact. So I thought I had the skills (April, 2018)."

6.8 New information

The theme new information was derived from narratives whereby the participants mentioned information they learned during the course of this project. Commentary in this theme may have addressed what the participants learned in courses, during meetings with advisors or other academic personnel with insight about their projects, or information learned via working through their own research projects:

"For This week I have learned using and organizing data and guided question that lead me to decision make so depend on that I can make my decision on analyzing the data help me arrive about these decisions (March, 2018)."

"But yeah what I'm learning is teaching style and my belief on becoming an expert in academia I think is very good at it because and what it says to me and what I think is most important in creating success in the classroom as a full time or part time is to be knowledgeable of your material and to be mindful of your audience (March, 2018)."

"But what I see those skills as being very useful and meaningful not for this research project that I'm working on but everything that happens every class that I take is geared towards making me a better professional a more learning person but also an expert in whatever field whatever path I choose to take whatever direction I am led in that I'll be very good and efficient in what I do and so I enjoy being exposed to varied skills varied skillsets (April, 2018)."

"...I'm learning a lot of new things, things outside of engineering, things outside of um outside of what I've been a bit used to (April, 2018)."

6.9 Future anticipation (academic "to-do")

Future anticipation refers to plans the participants discussed for improvement with respect to their course completion or with their research project. In many cases, the participants discussed the process about what they think will happen as they progress in their respective programs.

“For the time factor by starting the research as early as possible that absolutely can help me manage the time factor. For example I talk to many students about how you manage the time factor. So most student’s responses say that whenever I start the research the earlier it end up in finishing the earlier in frame time you have (February, 2018).”

“Hopefully I’ll be publishing a paper on it or we’ll be publishing a paper together on it. It looks challenging for me because um I’ve never published a paper before. Um it’s something that I should have done but I’ve never gotten the opportunity to get involved in research that warrants me to publish a paper (February, 2018).”

“I just need to appropriate more time for my research work. I know I need to. I need to appropriate more time for my research work because time is going and I’m getting deeper and deeper into to it gradually (March, 2018).”

“...but next, the end of 2019, No, 2018 yea, 2019 end, I should you know have a paper well on its way and again we’re taking the credit course I have to complete and I’m not sure what else. Yea there is a DQ disqualifying exam that I have to take and I take that in 2020 (May, 2018).”

6.10 Problem-solution focus

The problem-solution focus theme includes narratives that identify problems the participants may have encountered thus far in their courses and/or their research projects and their plans to address or correct those problems.

“Um so like I said one current challenge is managing my time, managing my time. Splitting my time within the three courses and my research work. I mean there are deliverables every week, literally every week. You know my courses, and um I’ve seen that um spending too much time on one particular course usually has ripple effects on another course or my personal research work. So I need to properly allocate my time within each of these courses. I need to properly allocate enough time for my research work. (February, 2018).”

“But the beauty of doing research at (redacted words) is, a lot of materials are accessible. There’s a lot you can do without going into the physical building. You will some, some volumes sporadically are available online. You can reserve books online, from (redacted words), you can barrow books from other institutions online through interlibrary loan. So it is a very resourceful place especially if you know what you are looking for (March, 2018).”

“...how I intend to address it um ok and I am working with a lot of online videos and documents I came across also and I also plan to contact the customer support and um specially tell them the request I need and how I can easily extract the data from the database that I need from them and so hopefully um I hope I get satisfactory and um hopefully I get satisfactory from the customer support and hopefully I get all the data I need if everything works out and I um piece them together (June, 2018).”

6.11. Evaluating Construct Interactions

From the sampled responses above, there was significant indication that some of the constructs exhibited intersections or are correlated. Based on the frequency data over time, a correlation matrix was extracted as shown in Figure 2. The statistical significance of the correlations was tested using a t-test measure with two degrees of freedom. However, it is important to note that only the hatched bubbles indicate significance of the correlation for the two-tailed test at a significance level with p -value of 5% indicating that there is a significant linear relationship between the two constructs in the population. The constructs are all positively correlated, with magnitude of correlation corresponding to the size of the bubble. This is shown by the checked bubbles intersecting any two pairs of measures in Figure 2. It is evident that Anticipatory Cognition is correlated and significant to several of the measures, but lacks significance against stereotype threat, isolation, extant knowledge and future anticipation. For example, the weaker the participants infer the stereotype threat, the higher is their attention and focus to solving their research problem. It is also evident from this Figure that Academic Self Efficacy is predominantly correlated (and significant) with all the other constructs. The intriguing result from this figure is that Stereotype Threat and Identity are on average insignificantly correlated with the other constructs. This implies that their presence may not be ameliorated by improvements in the other constructs. It is important to note the absence of correlation between Solution Focus and Perseverance. On initial thoughts, this appears to be counter-intuitive. However, a deeper scrutiny shows that the response of Perseverance to constructs such as Isolation and New Information indicates that Perseverance is less about the research agenda, but more about the environmental influences on the participants.

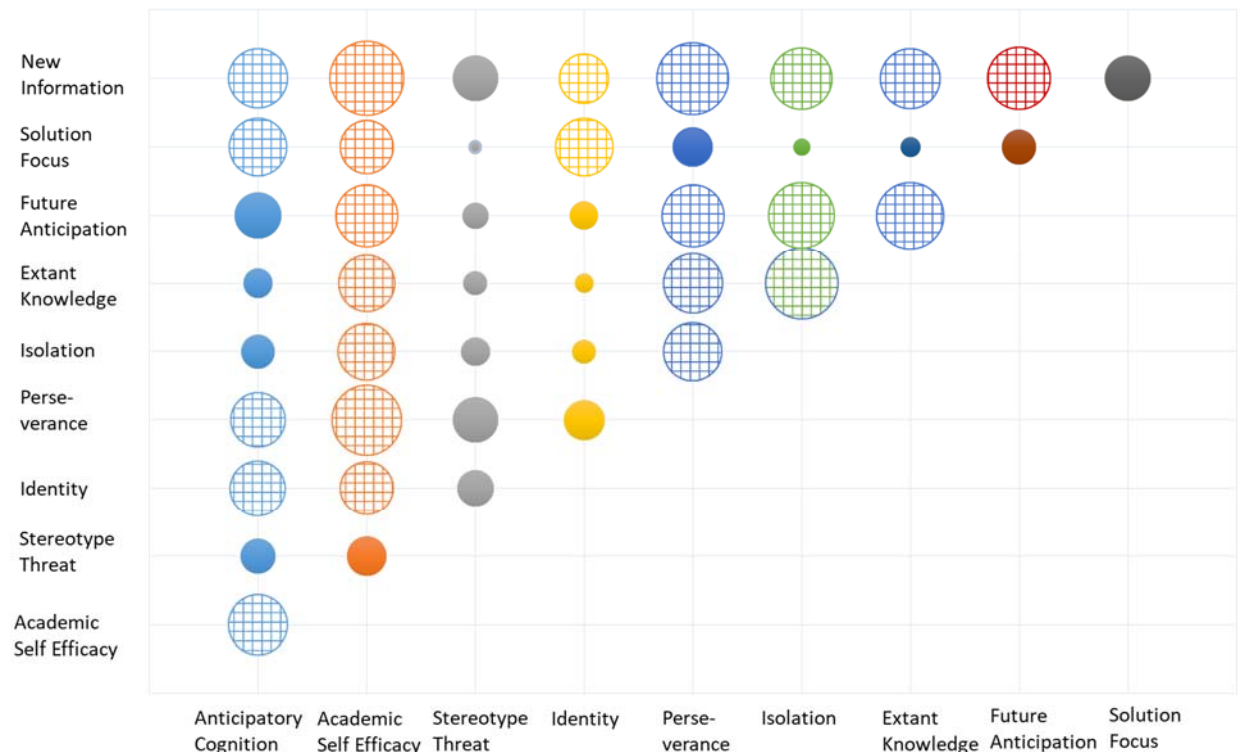


Figure 2. Correlation between constructs (significance at $p=0.05$ are hatched)

6.12. Evaluating Academic Self Efficacy

The following charts provide snapshots of the evolution of the participants over time on five metrics of academic evaluations. Figure 3 shows the students' level of understanding the knowledge base of cognitive communications. It is evident in this figure that the students rating ranging from L1 which is “poorly” to L5 which is “very well” appreciated from the absence of very well to somewhat of an increase over the 11-month period.

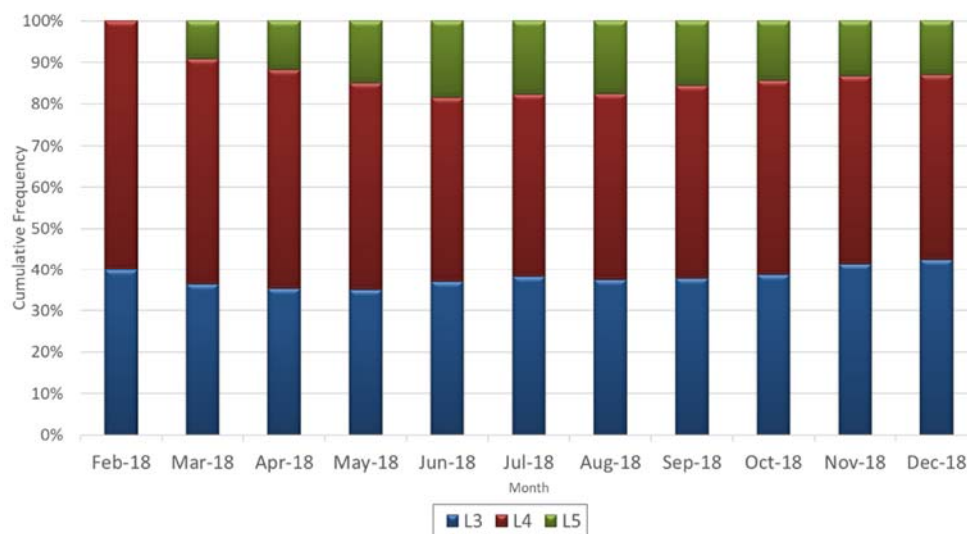


Figure 3: Participants' response to their understanding cognitive communication.

In Figure 4, we see a more pronounced appreciation of these students working in teams. Evidently, the initial cultural shock appears to taper-off after the first couple of months as they become very well accustomed to the system.

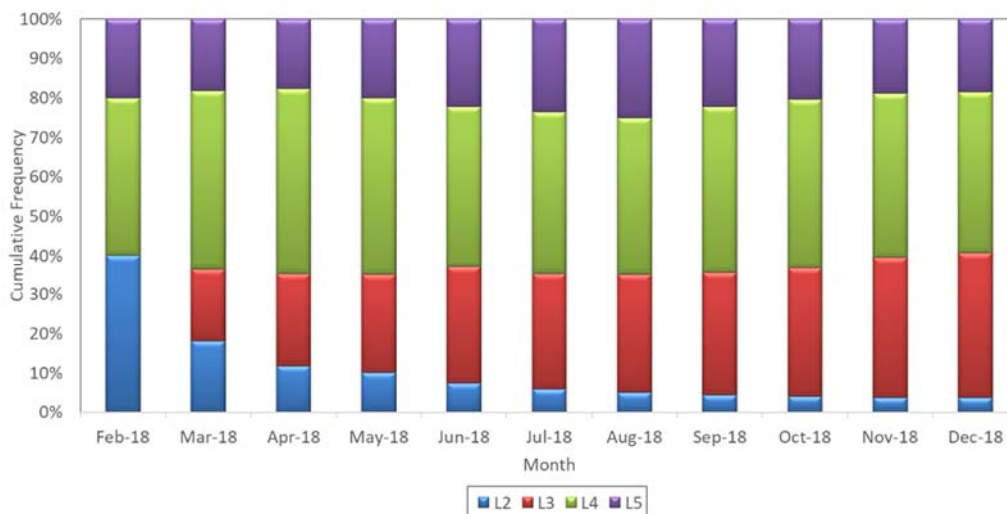


Figure 4: Participants' appreciation of working in teams.

The same trends are observed in Figures 5 – 8 on their understanding of class discussions, translating problems into research, finding the relevant journals for their research and practicing or applying skills related to their research, respectively.

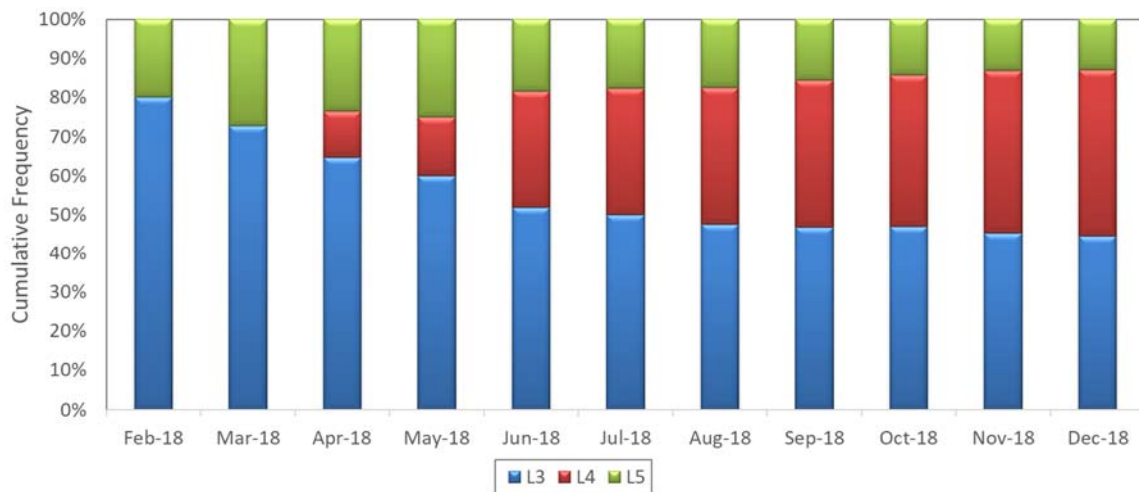


Figure 5: Participants' classroom understanding.

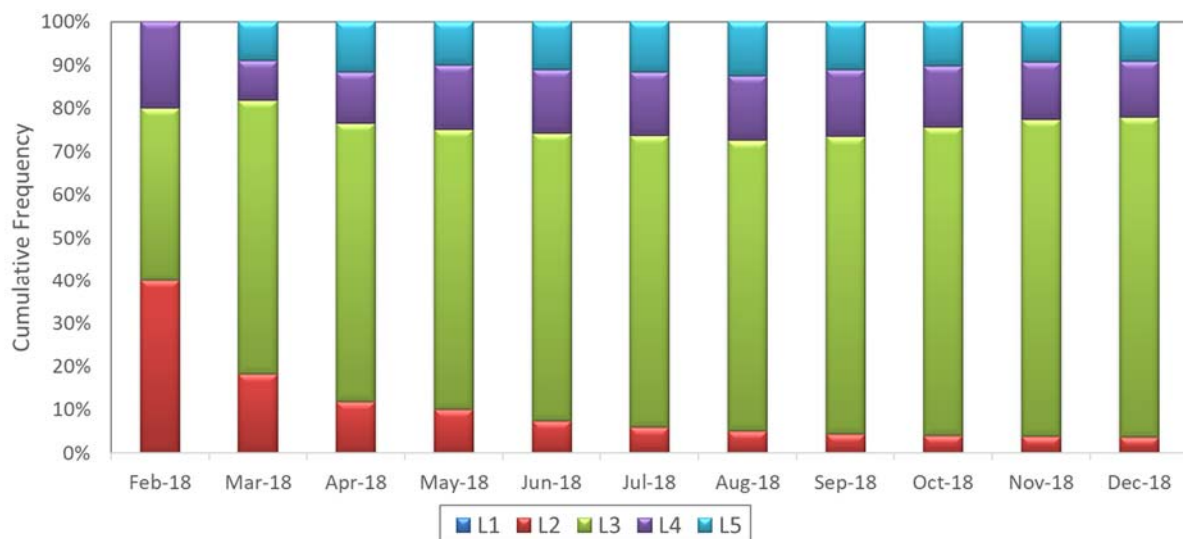


Figure 6: Participants' improvement in translating problems into research questions.

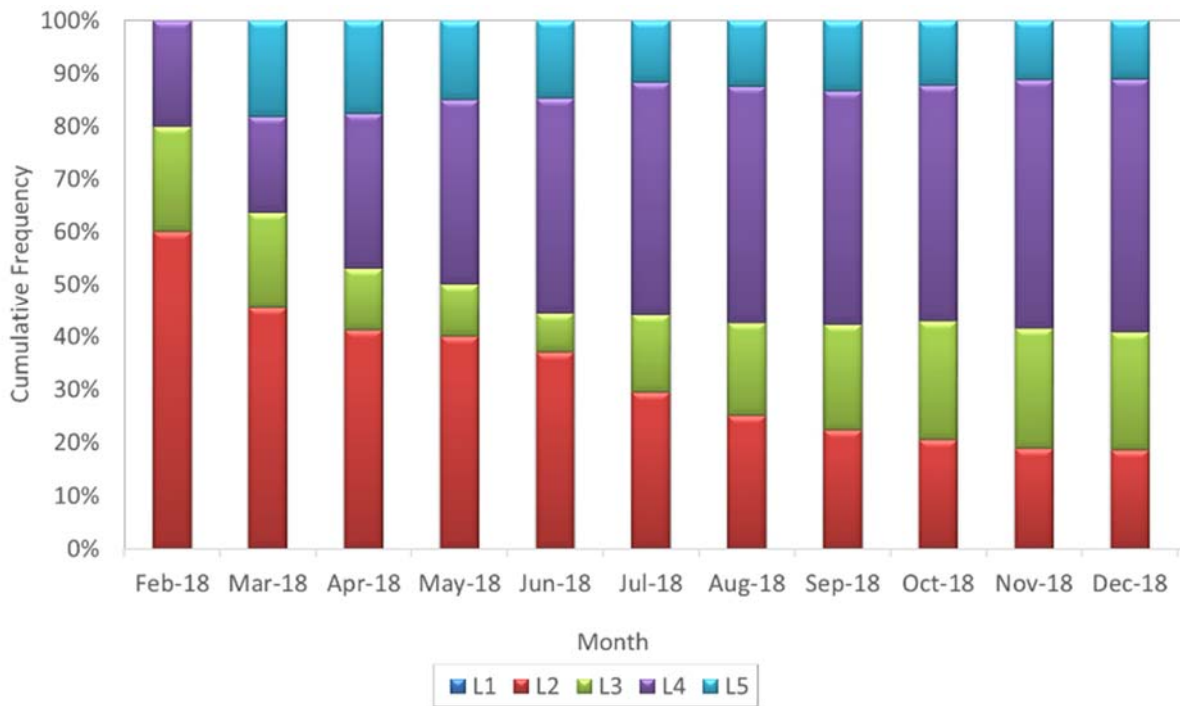


Figure 7: Participants' ability to find journals related to their research.

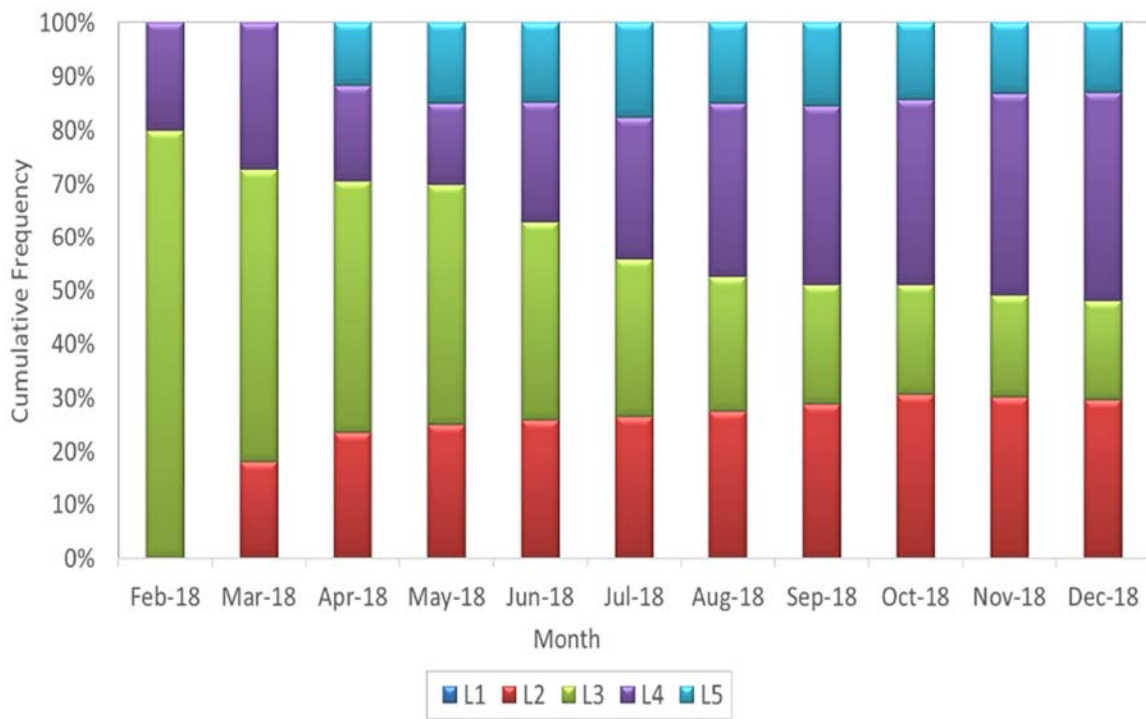


Figure 8: Participants' ability to apply skills related to research.

7. Implications

Based on the thematic analysis, it appears the participants, in general, have shifted from new Ph.D. graduate students who have limited knowledge of what is to come, to somewhat seasoned graduate students who have a better understanding of the challenges ahead, how to overcome them, and the resources and information they need to successfully navigate their engineering Ph.D. program. For example, the challenges they experienced early in the program (time management, course completion, etc.) do not appear to have dissipated but rather become embedded in the broader challenge they face in terms of completing their dissertation research projects. Their initial conversations about time management were focused on completing course work and research at the same time. However, their later discussions about time management centered on their timelines for moving through each step of their dissertation research; at this point, course work time management seemed to be understood and automatically implied.

In a similar vein, initial discussions about academic self-efficacy seemed to center on their abilities and capabilities of completing their course assignments, making it to and successfully passing qualifying exams, and developing an “advisor worthy” research topic. Towards the latter months of the project, the participants’ discussions about academic self-efficacy shifted direction and emphasized their abilities to complete the dissertation projects they had since developed while recognizing that obstacles that occurred were less about their own abilities and more so about the type of research project they were aiming to complete. At that point, most of the participants seemed to feel confident that they were “experts” in the area because they were able to fully articulate their research ideas and plans and were able to discuss barriers to completion and provide suggestions for overcoming those barriers.

These examples are just a few that describe the growth of the participants from “student researchers” to “independent researchers.” Narratives supplied for anticipatory cognition and academic self-efficacy appear to vary in count and quality of anticipation over time. This makes sense because it is expected that as student learn and grow throughout their graduate studies, they would become better at anticipating problems and develop stronger feelings about their own capabilities. However, the narratives given for stereotype threat and identity seemed to stay relatively unchanged in number, but with a deeper implication overtime. This also makes sense if there is consideration for their early thoughts about the impact of being diaspora students in an engineering PhD program. In the first month of the project, there was little concern about how they would be viewed at their respective universities (as black diaspora students) and by their families. By the latter months of the project, participants displayed no concerns in these areas, but more along what the program expects of them. As for the emerging codes, there was no distinct pattern (increase or decrease) in the thoughts participants’ shared but that is to be expected since those codes only manifested because of issues the participants were experiencing at the time of their recordings. Essentially, an issue that may have arisen in one week, may not have ever manifested again during the data collection period.

It should be noted that this research did not examine whether the students identify as African Americans or not. The Identity construct focused on their perceptions as engineers and how they convey such self-recognition to others and their family members.

8. Conclusion

The research described in this paper highlights some critical outcomes on the factors that influence the performance of underrepresented minorities in engineering doctoral programs. In a concurrent scheme, (i) the process calibrates participants' progress in their course works and research on their comprehension and application of impactful, data-driven research skills, and (ii) the metacognitive development process examines the effects of anticipatory cognition, stereotype threat, identity, and academic self-efficacy as the participants progress in skills acquisition.

With the passage of time, participants demonstrated increase in educational awareness transitioning from new PhD students with limited knowledge to students who have a better understanding of the challenges and have ideas on how to overcome them with the resources and information required. However, some of the challenges such as time management became embedded in the broader challenge of completing their dissertation. Likewise, the focus on academic self-efficacy related to passing their doctoral qualifying exams changed to a focus on satisfying their dissertation requirements. It is critical to note here that the challenges observed were less about their own abilities, but more on the actual research question they wish to address. As illustrated, it is evident that with the passage of time, the participants have a better grasp of anticipating problems and developing stronger thoughts about their own capabilities. However, the narratives given for stereotype threat and identity seemed to decrease in number and depth overtime. This also makes sense if there is consideration for their early thoughts about the impact of being black diaspora students in an engineering PhD program. In the first month of the project, there was little concern about how they would be viewed at their respective universities and by their families. By the latter months of the project, participants displayed no concerns in these areas. It should be noted that one of the universities is an HBCU, while at the other university, the advisor is also a black diaspora faculty. These factors could affect students' experiences.

This study finds that constructs such as Anticipatory Cognition, Academic Self Efficacy, Stereotype Threat and Identity are dominant. There are also significant correlations between the constructs and some of the emergent phenomena. For example, Academic Self Efficacy is predominantly correlated with all the other constructs. However, we found some intriguing outcomes. For example, Stereotype Threat and Identity issues may not be ameliorated by improvements in the other constructs. This project is only midway through. As data collection is ongoing, we anticipate that these preliminary results may be strengthened.

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