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Course Technology & First-year Undergraduates at an HBCU: Technostress, Role Stress, & Productivity

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Abstract: Equitably meeting the demands of an uncertain future requires diversity in science, technology, engineering, and math (STEM). Historically Black colleges and universities are more successful in producing graduates of color compared to predominately White institutions, but STEM retention is a universal problem in higher education. This study expands the retention discussion by exploring differences in STEM and non-STEM students regarding course technology requirements, technostress, role stress, and productivity among first-year undergraduates at a historically Black university in southeastern United States. Although variable among participants, technostress and productivity did not differ between STEM and non-STEM students. However, STEM students use fewer technological tools and experience greater role stress relative to non-STEM students. While role stress is dependent upon major and levels of technostress, use of a new digital tool did not impact student perception of role stress. This study has implications for recommendations to improve student retention and success in STEM. In addition to interactive student-centered instruction, introductory STEM courses may demonstrate greater student success with diverse digital applications.

Keywords: retention, course technology, technostress, role stress, productivity
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Introduction

An increase in science, technology, engineering, and math (STEM) professionals is needed to meet projected workforce demands (Byars-Winston & Dahlberg, 2019; National Center for Science and Engineering Statistics, 2023; National Science Board, 2022). Increasing the diversity of the STEM workforce will promote social equity, advances in technology, and a greater capacity to address complex and unforeseen issues of the 21st century (Byars-Winston & Dahlberg, 2019; Mim, 2019). While under-represented minorities make up 9% of STEM graduates, they account for 28.5% of the U.S. population (National Science Board, 2022). Historically Black colleges and universities (HBCUs) produce well-trained students of color for STEM fields (National Science Board, 2022). Even though they make up 3% of the nation's four-year colleges and universities, HBCUs award a disproportionate number of STEM bachelor's degrees, approximately 18%, to their students (United Negro College Fund, 2019). While successful in producing STEM graduates, HBCUs suffer from a universal problem in higher education: many more students enter college declaring a STEM major than graduate with a STEM degree (Belser et al., 2017; Gansemer-Topf et al., 2017; Maton et al., 2000; Seymour & Hewitt, 1997). Solutions have included undergraduate research experiences and mentoring (Foertsch, 2019; Li Huang et al., 2021; Spaulding et al., 2022; Summers & Hrabowski, 2006), and improvements in academic advising and student financial support (Li Huang et al., 2021). While these programs have shown some success in improving undergraduate STEM persistence, particularly for minority students, retention remains a problem.

Factors that influence STEM retention, particularly among Black students, include secondary school preparation and resources, undergraduate academic advising, and characteristics of first-year undergraduate STEM courses. Predominantly African American secondary schools are under-resourced regarding access to advanced course work, such as Advanced Placement (AP) courses (Klopfenstein, 2004; Lucas & Berends, 2007; Margolis et al., 2008). In turn, these schools graduate students who may be interested in STEM, but underprepared for the rigor of undergraduate STEM coursework (Kao & Thompson, 2003; Tyson, 2011). Academic advising plays a significant role in helping students navigate a new environment, select appropriate majors, and persist to graduation (Fox & Martin, 2017). The reality of a STEM student's first-year experience with advisement is often impersonal and disorganized, leading to a sense of isolation and lack of support (Sithole et al., 2017). Moreover, the coursework associated with STEM majors in the first year does little to promote persistence: large enrollment courses function as gateway or "weed out" courses (Seymour & Hewitt, 1997), acting more as barriers to learning rather than preparation for advanced work. When combined with boring or uninspiring course work and instructional techniques (i.e., lecture) (American Association for the Advancement of Science, 2011), it is no surprise that students often end their first year with poor STEM grades (Hurtado et al., 2010; Seymour & Hewitt, 1997), leading many to leave the major.

There is movement to improve the quality of instruction and management of introductory STEM courses. Institution-wide use of learning management systems (LMS), such as Blackboard and Canvas, allow instructors of large-enrollment courses to streamline and track assignments, distribute materials, and communicate with students (Lonn & Teasley, 2009; Reigeluth et al., 2008; Vega & Meaders, 2023). As a result, students have more consistent access to learning materials and know where they stand in terms of course performance (Lonn & Teasley, 2009). Instructors are implementing diverse digital tools and applications (DTAs) to engage students with disciplinary content. For example, virtual reality applications show promise within STEM fields to promote student interest and learning (Johnston et al., 2018; Maresky et al., 2019; Moro et al., 2017). These technological changes illustrate an attempt to address the issue of high failure introductory weed out courses associated with STEM majors.

The heavy reliance on technology, however, may be generating an unintended consequence. If students are overloaded with unfamiliar DTAs during their first-semester experience, it may induce stress associated with technology use, or technostress, which could potentially influence student decisions to persist or depart. Understanding the role of course technology, or the LMS and associated DTAs required for coursework, and its relationship with technostress may help contextualize the issue of STEM retention. Thus, the purpose of this study is to explore course technology requirements and technostress among first-year undergraduate students at an HBCU, with a specific focus on differences between STEM and non-STEM students.

Undergraduates and Technostress

Digital Natives

Current undergraduate students are called digital natives due to the ubiquitous influence of the internet and digital devices during their lifetimes (Brooks & Davis, 2018; Prensky, 2001; Rothman, 2014). The global pandemic exacerbated this generation's use of educational technology by ushering in a period in which all learning was remote and virtual as educators and students were forced to adjust to teaching and learning online (Al-Tammemi et al., 2022; Hodges et al., 2020). College students spend 8-10 hours a day engaged with cell phones or other forms of technology (Roberts et al., 2014), of which 3-4 hours is for academic purposes (Galanek et al., 2018), while 41% of secondary teachers report high school students spend more than five hours a day using educational technology (Fittes, 2022). Despite the return to in-person education, the reliance on technology for learning has continued.

Technostress, Role Stress, & Productivity

Technostress is the stress associated with the use of technology and has been associated with declines in workplace productivity and job satisfaction (Brod, 1984; Qi, 2019; Tarafdar et al., 2007). Technostress includes the following components: techno-overload, or working faster and longer hours; techno-invasion, or the blurring of professional and personal lives due to constant connectivity and reachability; techno-complexity, or the increasing complexity of technology requiring users to spend more time and effort to learn new applications; and techno-insecurity and techno-uncertainty, which refer to users' worries and fears regarding changing technologies (Qi, 2019; Tarafdar et al., 2007).

In professional workplace environments technostress is associated with role stress, and both factors negatively impact individual productivity (Ragu-Nathan et al., 2008; Tarafdar et al., 2007, 2011). Role stress is a combination of two factors: role conflict refers to a situation in which an individual is tasked with fulfilling conflicting responsibilities or obligations; and role overload occurs when there is too much work to do or the work is too difficult to accomplish (Tarafdar et al., 2007). Productivity can be viewed as meeting the responsibilities and demands of one's position successfully through the accomplishment of tasks. Experiences of technostress amplify role stress, and both factors reduce workplace productivity.

Although initially presented as an experience with negative consequences, technostress has the capacity to generate positive outcomes, such as improving performance, efficiency, and innovation (Salazar-Concha et al., 2021; Tarafdar et al., 2019). How an individual responds to technostress, positively or negatively, is based upon the "personality of an individual and the reaction to the trigger situation" (Salazar-Concha et al., 2021, p. 2). Consequently, technostress is less a stimulus or response, but more a process in which the presence of technology in one's environment requires a change in the behavior of an individual setting into motion psychological, physical, and behavior coping responses (Tarafdar et al., 2019). The likelihood of a positive outcome is increased when organizations help employees improve technology self-efficacy and literacy (Ragu-Nathan et al., 2008; Tarafdar et al., 2015). Therefore, the effect of technostress could be positive or negative depending on individual characteristics and organization supports.

Technostress in Education

Much of the research investigating technostress comes from the fields of communications and information systems (Salazar-Concha et al., 2021), although some work has emerged in education. Upon integration of a new technology, teachers often face challenges adapting to new workflows, which sets the stage for poorer performance and job satisfaction (Al-Fudail & Mellar, 2008; Francom, 2023; Li & Wang, 2021; Weems-Landingham, 2021). The role of technostress on students, however, has been less studied, likely due to the assumption that digital natives can quickly adapt to and effectively use technology for learning. In a large-scale observational study of university students in Paraguay, the majority of students reported low or moderate levels of technostress, which was significantly related to overall levels of anxiety and depression (Torales et al., 2022). In terms of productivity, students reporting moderate levels of technostress also reported reductions in the quality of academic work, the amount of work completed, and efficiency (Upadhyaya & Vrinda, 2021). Other studies found that online assessments resulted in test anxiety, computer anxiety, and technostress due to challenges with nonvisible or nonfunctional buttons, browser incompatibility, internet speed and reliability, and the need for multiple test resets and attempts (Al-Tammemi et al., 2022; Davies, 2015). Oladosu et al. (2020) found that increased reliance on smart devices generated technostress among students, which had a negative impact on their ability to learn with such devices. These studies demonstrate that the experience of technostress among students and teachers warrants further investigation to understand its impact on educational outcomes.

Research Objective

The objective of this study is to understand the relationship between course technology, technostress, role stress, and productivity among first-semester students at an HBCU. It is expected that students reporting a greater quantity of required DTAs in their academic courses will demonstrate higher levels of technostress and role stress, which will negatively influence productivity. Differences in technostress, role stress, and productivity after use of familiar versus new technological applications are also examined. This study addresses the following research questions:

1. How do first-year students rate their experiences with technostress, role stress, and productivity during their first-semester at an HBCU (RQ 1)?
2. Can undergraduate major category (STEM vs. non-STEM) and the quantity of DTAs explain variation in technostress, role stress, and productivity among first-year students (RQ 2)?
3. Is there a difference in technostress, role stress, and productivity among students using familiar versus unfamiliar digital applications for course work (RQ 3)?

Methods

The first part of this study was an observational project in which technostress among first-year undergraduates at an HBCU was quantified. The dependent variables of interest were the composite scores of technostress, role stress, and productivity. The independent variables included the *total* number of DTAs students reported using in their course work, the number of *new* DTAs students reported, and major. STEM majors included biology, chemistry, computer science/cyber-security, mathematics, physics, and psychology. Everything else was categorized as non-STEM majors and used as the reference category. The second part was a quasi-experimental study in which technostress, role stress, and productivity were measured in response to a new course technology requirement.

Observational Study

For the descriptive study, participants were recruited from two courses: non-STEM students from a general education biological sciences course taught by the researcher, and STEM students from a first-year seminar course taught by STEM faculty. Demographic data, including race, first generation status, socioeconomic status (SES), gender, and high school GPA were pulled from institutional records to control for variation within sub-groups. SES was represented by Pell-eligible status, which refers to undergraduate students demonstrating exceptional financial need and qualify for federal Pell Grants (Office of the US Department of Education, n.d.). Sixty-seven students participated, of which 60% were STEM majors and 40% were non-STEM majors. Race and gender were reported for 64 of the respondents. Seventy-seven percent were female and 23% male, while 70.3% identified as Black or African American, 9.4% as Hispanic, and 20.3% as two or more races. First-generation and SES were reported for 48 out of the 67 participants, of which 17% were first-generation and 69% were Pell-eligible. The mean high school GPA of the participants was 3.58 (0.45 *SD*).

Students completed a 5-point Likert survey on technostress, role stress, and productivity (Tarafdar et al., 2007) six weeks into the semester (Appendix). Survey items were adapted for educational settings. For example, one of the original survey items was "I am forced by this technology to do more work than I can handle." This statement was rephrased to read "course technology forces me to do more work than I can handle." Responses were re-coded as numerical values (*strongly agree* = 5, *somewhat agree* = 4, *neither agree nor disagree* = 3, *somewhat disagree* = 2, and *strongly disagree* = 1) and summed to produce a single score for each metric: technostress, role stress, and productivity. All technostress sub-categories (overload, insecurity, complexity, uncertainty, and invasion) and elements of role stress (role overload and conflict) were maintained. The original survey included 36 statements; the revised version used in this study consisted of 33 statements. Twenty-two items measured technostress; 7 items measured role stress; and 4 items measured productivity.

The survey also assessed course technology requirements. A list of DTAs was generated in consult with the institutional center for online learning, which tracks course technology use. From this list, students selected the tools and applications they were required to use across all their courses, and then indicated how many of those tools or applications were new to them this year. Among the participants, the five most frequently reported DTAs were as follows: 97% use Canvas (institutional LMS), 79% use Microsoft Office applications, 69% use Educosoft (software application for math courses), 61% use Achieve (adaptive learning tool produced by Macmillan Publishers), and 46% use EON-XR (augmented virtual reality application) (Table 1).

Table 1

Top five DTAs by grouping and the percentage of students reporting DTA use for academic purposes.

All (*n* = 67)		**STEM (*n* = 40)**		**Non-STEM (*n* = 27)**	
DTA	**%**	**DTA**	**%**	**DTA**	**%**
Canvas	97	Canvas	95	Canvas	100
Microsoft Office	79	Microsoft Office	75	Edpuzzle	96
Educosoft	69	Lockdown Browser	62	EON-XR	96
Achieve	61	Educosoft	58	Educosoft	85
EON-XR	46	Achieve	52	Microsoft Office	85

Quasi-experimental Study

The second component of the study involved measuring student technostress in response to new technology requirements. Forty-six undergraduate students in an introductory biology course for non-STEM majors participated in the study in 2023. Students were randomly assigned to experimental or control conditions. The control condition involved students completing an Edpuzzle assignment on cell membrane structure consisting of a video (Amoeba Sisters, 2018) and four multiple choice questions. The experimental condition involved students completing an augmented reality (AR) assignment on the same topic. The AR lesson was created by the researcher using EON-XR software and consisted of a labeled 3-dimensional model of the cell membrane, audio recordings, video, and assessment questions (multiple-choice, identify, and locate). Forty-six students participated in the quasi-experimental study, of which 21 completed the Edpuzzle assignment (control group) and 25 completed the EON-XR assignment (experimental group). All students had previous experience completing Edpuzzle assignments in the class, but no prior experience with the EON-XR application.

After finishing the Edpuzzle and AR assignments, students completed the survey to capture technostress, role stress, and productivity. The technostress portion of the survey was reduced to capturing techno-overload, complexity, and uncertainty as these sub-categories contained items that could be adapted to one-time use of technology. One item from techno-insecurity was also included to understand student perception of the technology on course performance. Similarly, some role stress statements were excluded as they referenced a longer time-scale rather than a single in-class assignment. Thirteen items measured technostress, three items measured role stress, and all items for productivity were retained. Likert item responses were re-coded as numerical values (*strongly agree* = 5, *somewhat agree* = 4, *neither agree nor disagree* = 3, *somewhat disagree* = 2, and *strongly disagree* = 1) and summed to produce technostress, role stress, and productivity scores.

Statistical Analysis

For the observational portion of the study, chi-square tests were used to compare STEM and non-STEM groups for the following demographic variables: gender, race, Pell-eligible status, and first-generation status. Chi-square was also used in the quasi-experimental portion of the study to identify differences between control and experimental groups for gender and race. Independent t-tests were used to identify group differences (STEM and non-STEM; control and experimental) in high school GPA and DTAs. Multiple linear regression was used to understand the relationships between technostress and DTAs and major; role stress and technostress, DTAs, and major; and productivity and role, stress, technostress, DTAs, and major. Categorical variables (major, learning mode, gender, first generation status, Pell-eligible, and race) were dummy-coded prior to analysis. Reference categories were as follows: non-STEM, Edpuzzle (control), female, not first-generation, not Pell-eligible, and Black or African American. All analysis was completed using SPSS software.

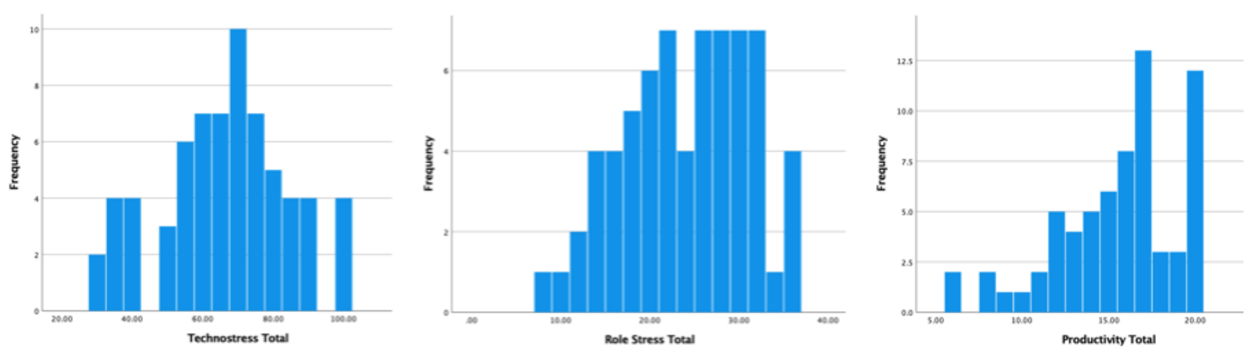
Results

RQ 1: Experiences of Technostress, Role Stress, and Productivity

Variation existed in how students rated their experiences with technostress, role stress, and productivity. The distribution of technostress scores was normal with a range of 30 – 102 (Figure 1). The mean technostress score was 66.2 (17.8 *SD*) out of a possible 110. Role stress scores were normally distributed with a range of 8 – 35 and a mean of 23.5 (6.9 *SD*). Lastly, the distribution of productivity scores was normal with a range of 6 – 20. The mean productivity score was 15.5 (3.6 *SD*). Mean subcomponent scores of each metric are comparable with previous studies (Ragu-Nathan et al. 2008; Tarafdar et al, 2007) suggesting the total technostress, role stress, and productivity scores reported here are similar to workforce professionals.

Figure 1

Distribution of technostress, role stress, and productivity scores.



RQ 2: Influence of DTAs and Major on Technostress, Role Stress, and Productivity

The mean number of DTAs required of these students across all their courses was 7.6 (3.0 *SD*), of which 3.1 (1.8 *SD*) were new or unfamiliar to the students. For STEM students, the top five frequently used DTAs were as follows: 95% use Canvas; 75% use Microsoft Office applications; 62% use Lockdown Browser; 58% use Educosoft; and 52% use Achieve (Table 1). The top five list was slightly different for non-STEM students: 100% use Canvas; 96% use Edpuzzle; 96% use EON-XR; 85% use Educosoft; and 85% use Microsoft Office applications.

Non-STEM students use more total and new DTAs relative to STEM students. The mean total DTAs for non-STEM students (*n* = 27) was 9.3 (2.8 *SD*) compared to a mean of 6.5 (2.6 *SD*) for STEM students (*n* = 40). Variances between the groups were equal (Levene's test, $F = 0.26$, $p = .62$). An independent t-test showed that the non-STEM students used a significantly larger number of digital tools or applications, t (65) = -4.2, $p < .001$. Analysis of effect size suggests the difference between the two means was large (Cohen's *d*, $d = -1.1$). The mean number of new DTAs for non-STEM students (*n* = 27) was 3.8 (1.7 *SD*) compared to a mean of 2.6 (1.7 *SD*) for STEM students (*n* = 40). Variances between the groups were equal (Levene's test, $F = 0.02$, $p = .89$). An independent t-test showed that the non-STEM students used a significantly larger number of new digital tools or applications, t (65) = -2.7, $p = .009$. Analysis of effect size suggests the difference between the two means was moderate (Cohen's *d*, $d = -0.68$).

Demographic variables included gender, race, Pell-eligible status, and first-generation status. Three categories of race were reported: Black/African American, Hispanic, and 2 or more races. However, racial groups were collapsed into two categories to account for the small sample size into two of the groups. The remaining race categories were Black/African American and other. Analysis indicated that STEM and non-STEM groups did not have different proportions of participants based on gender [χ^2 (1) = 0.04, $p = .84$], race [χ^2 (1) = 0.30, $p = .59$], Pell-eligible status [χ^2 (1) = 0.81, $p = .37$], and first-generation status [χ^2 (1) = 0.15, $p = .70$] (Table 2). Moreover, the mean high school GPA was not different by group [independent t-test, t (62) = -0.54, $p = 0.60$].

Table 2

Demographic data by major category. Values represent proportion of sample except for high school GPA (HS GPA), where value represents mean (SD).

		STEM	Non-STEM	Test Statistic	*p*
Gender	Female	0.76	0.78	χ^2, 0.04	.84
	Male	0.24	0.22		
Race	Black/AA	0.73	0.67	χ^2, 0.30	.59
	Other	0.27	0.33		
First-generation	Yes	0.14	0.19	χ^2, 0.15	.70
	No	0.86	0.81		
Pell-eligible	Yes	0.62	0.74	χ^2, 0.81	.37
	No	0.38	0.26		
HS GPA		3.6 (0.46)	3.6 (0.45)	*t*, -0.54	.60

The distribution of technostress scores was normal, and the total DTAs and new DTAs appeared to show a linear association with the dependent variable. Multicollinearity between total tools or applications and new tools or applications was moderate at 0.452, though not high enough for concern. Linear multiple regression was used to predict technostress score by accounting for major, first-generation status, Pell-eligible status, gender, race, high school GPA, total DTAs, and new DTAs. To account for a potential interaction between major and DTA, an interaction variable composed of STEM*total DTA was added to the analysis. Analysis of variance suggested that the resulting model was not significant (F = 1.18, p = .33), and the adjusted R-square value of .04 suggests that only 4% of the variation in technostress can be accounted for by these explanatory variables.

Role stress was predicted using two multiple regression models. The first included technostress, major, total DTAs, new DTAs, and all demographic variables as predictors. The second model included everything with the addition of the major-DTA interaction. Role stress scores were normally distributed and demonstrated linear association with technostress, total DTAs, and new DTAs. Multicollinearity between continuous variables was 0.4 or below. The first model was significant (F = 4.0, p = .001) with an adjusted R-square value of 0.40. Coefficients for major and technostress were significant (Table 3). STEM majors have role stress scores 4.0 points higher than non-STEM majors after controlling for DTAs, technostress, and demographic variables. In addition, for every one point increase in technostress score, role stress increases by 0.2 points. The second model included the interaction term and was also significant (F = 4.2, p < .001) with an adjusted R-square value of 0.40. The coefficients for technostress were significant (Table 3); for every one point increase in technostress score, role stress increases by 0.22 points. Although not significant, the interaction variable reveals the potential for differences in role stress by major dependent upon total DTAs. For STEM majors, it appears that role stress increases with each DTA, while for non-STEM majors, role stress decreases with each DTA.

Productivity was predicted using role stress, technostress, major, total DTAs, new DTAs, the interaction term, and all demographic variables. Productivity scores demonstrated linear association with technostress, role stress, total DTAs, and new DTAs. Multicollinearity between continuous variables were 0.6 or below. Analysis of variance suggested that the resulting model was not significant (F = 1.1, p = .38) with an adjusted R-square value of -0.003.

RQ 3: Influence of Learning Mode on Technostress, Role Stress, & Productivity

In the quasi-experimental portion of the study, differences in technostress, role stress, and productivity were examined among groups using a familiar (Edpuzzle) versus new (EON-XR) DTA. Demographic variables included gender and race. Three categories of race were reported: Black/African American, Hispanic, and 2 or more races. However, racial groups were collapsed into two categories to account for the small sample size into one of the groups. The remaining race categories were Black/African American and other. Analysis indicated that control and experimental groups did not have different proportions of participants based on gender [χ^2 (1) = 0.04, p = .85] or race [χ^2 (1) = 1.1, p = .30] (Table 4). Moreover, the mean high school GPA was not different by group [independent t-test, t (43) = -0.67, p = 0.51].

Table 3

Summary of hierarchical multiple linear regression coefficients for role stress.

	Model 1				*Model 2*			
Variable	***B***	***SE B***	***t***	***p***	***B***	***SE B***	***t***	***p***
Intercept	15.3	10.0	1.5	.14	24.7	10.9	2.3	.03
Gender*	-0.55	2.4	-0.23	.82	-0.69	2.3	-0.30	.76
Race[τ]	-0.22	1.9	-0.01	.99	-0.04	1.8	-0.21	.99
First-generation[β]	-1.1	2.2	-0.48	.63	-1.3	2.1	-0.60	.56
Pell-eligible[ε]	0.32	1.8	0.18	.86	-0.31	1.8	-0.17	.86
HS GPA	-2.1	2.1	-0.97	.34	-3.3	2.2	-1.5	.14
Technostress	0.20	0.05	4.3	< .001	0.22	0.05	4.8	< .001
Major**	4.0	2.0	2.0	.05	-5.1	5.2	-0.99	0.33
Total DTAs	-0.61	0.33	-0.19	.85	-0.66	0.44	-1.5	0.15
New DTAs	0.13	0.53	0.24	.81	0.14	0.52	0.28	0.78
Interaction term								
Major * Total DTA					1.1	0.59	1.9	.06

[*] Reference category was female.

[τ] Reference category was Black/AA.

[β] Reference category was not first-generation.

[ε] Reference category was not Pell-eligible.

[**] Reference category non-STEM.

Table 4

Demographic data by treatment category. Values represent proportion of sample except for high school GPA (HS GPA), where value represents mean (SD).

		Control	**Experimental**	**Test Statistic**	***p***
Gender	Female	0.67	0.64	χ^2, 0.04	.85
	Male	0.33	0.36		
Race	Black/AA	0.57	0.42	χ^2, 1.1	.30
	Other	0.43	0.58		
HS GPA		3.2 (0.37)	3.2 (0.51)	*t*, -0.67	.51

Technostress scores for the quasi-experimental test were normally distributed. Linear multiple regression was used to predict technostress score by accounting for learning mode, gender, race, and high school GPA. Analysis of variance suggested that the resulting model was not significant (F = 1.6, p = .19), and the adjusted R-square value of .05 suggests that only 5% of the variation in technostress can be accounted for by these explanatory variables.

Role stress was predicted using technostress, learning mode, gender, race, and high school GPA. Role stress scores were slightly positively skewed (1.2) and demonstrated linear association with technostress and high school GPA. Multicollinearty between technostress and high school GPA was -0.12. Analysis of variance suggested the resulting model was significant (F = 9.8, p < .001), and the adjusted R-square value of 0.50 suggests that 50% of the variation in role stress can be accounted for by explanatory variables. The coefficient for technostress was significant (Table 5); for every one point increase in technostress score, role stress increases by 0.22 points controlling for learning mode, gender, race, and high school GPA.

Productivity was predicted using role stress, technostress, learning mode, gender, race, and high school GPA. Productivity scores were slightly negatively skewed (-0.54) and demonstrated linear association with technostress, role stress, and high school GPA. Multicollinearity between technostress and high school GPA was -0.12; between role stress and high school GPA was -0.11; and between role stress and technostress was -.72. The high value for this latter pair suggests substantial overlap in variation explained by technostress and role stress. As role stress was limited in scope for the quasi-experimental test (only three items) and demonstrated overlap with technostress, it was removed from the model. Analysis of variance suggested that the resulting model was not significant (F = 1.1, p = .38), with an adjusted R-squared value of -0.095.

Discussion

This study set out to understand the impact of course technology on technostress, role stress, and productivity among first-year students at an HBCU with a particular focus on differences between STEM and non-STEM students. In addition, we explored if these variables differ between groups using familiar and new technology applications.

STEM vs. non-STEM Students

First-year students at an HBCU demonstrate variation in technostress, role stress, and productivity (RQ 1). While STEM majors use approximately 3.5 fewer total DTAs relative to non-STEM majors, quantity of DTAs does not explain variation in technostress, role stress, nor productivity among first-year undergraduates at an HBCU (RQ 2). Technostress and major are significant predictors of role stress, with STEM majors demonstrating higher role stress relative to non-STEM students. These results are similar to Tarafdar et al. (2007) who found that technostress was positively related to role stress among employees of U.S. based organizations. However, the present study was unable to confirm a direct relationship between technostress, role stress, and productivity. While Tarafdar et al. (2007) found that both technostress and role stress were negatively correlated with productivity, our results do not demonstrate the same relationship.

Table 5

Summary of multiple linear regression coefficients predicting role stress from technostress, learning mode, gender, race, and high school GPA.

Variable	*B*	*SE B*	*t*	*p*
Intercept	-0.58	2.7	-0.21	.83
Learning Mode*	-0.46	0.63	-0.73	.47
Technostress	0.22	0.03	6.4	< .001
Gender**	0.07	0.72	0.10	.92
Race[τ]	1.1	0.63	1.8	.08
HS GPA	-0.40	0.77	-0.53	.60

[*] Reference category was Edpuzzle (control).

[**] Reference category was female.

[τ] Reference category was Black/AA.

This study revealed significant differences between STEM and non-STEM students. First, STEM students use fewer total technology applications across their courses than non-STEM students. This suggests that non-STEM students enrolled in a STEM class for general education requirements use a greater diversity of DTAs relative to STEM students enrolled in a majority of STEM courses. Second, STEM students had higher role stress scores than non-STEM students. This means the technology requirements for STEM students result in a greater perceived mismatch between what is demanded of them and their capability. Despite these differences, technostress and productivity scores were not different between STEM and non-STEM students.

Non-STEM students use more DTAs and have lower levels of role stress. STEM students, however, use fewer DTAs and have higher levels of role stress. One possible explanation for these differences is an expectation for educational technology among digital natives (Gierdowski et al., 2020). Secondary and undergraduate students spend multiple hours per day engaged with technology for learning purposes (Fittes, 2022; Galanek et al., 2018; Roberts et al., 2014). When technology is available, students may be less stressed given their comfort level and familiarity using technology in the classroom. This idea is supported by more recent work suggesting some individuals respond to technostress positively, what researchers have termed "eustress" (Tarafdar et al., 2019). Rather than viewing technostress as a threat, individuals see it as a challenge and motivation to learn new skills, a perception that mirrors growth mindset (Dweck, 2006; Tarafdar et al., 2019).

Conversely, when technology use is restricted and students are presumably forced to learn with traditional materials (textbooks, paper notes, etc.), students may be more stressed given the requirement to conform to outdated modes of learning. Tarafdar et al. reported that professionals experiencing role stress are associated with a "reduced commitment…to their current organization" (2011, p. 118). The fact that STEM students report higher role stress than non-STEM students may be a factor explaining retention problems associated with STEM. However, rather than the role stress being associated with higher technostress, here it would seem that role stress may be associated with quantity of DTAs and is major dependent. Confirming such an explanation in the context of undergraduate students at an HBCU would require a larger-scale study employing a randomized experimental design. Moreover, a qualitative approach gauging individual student responses to technostress may illuminate how undergraduate students leverage it for a positive or negative outcome.

As mentioned previously, STEM retention at HBCUs is influenced by secondary school preparation and resources, undergraduate academic advising, and characteristics of first-year undergraduate STEM courses. The latter belongs to a category termed structural factors, and includes high standards and relevant curriculum (Li Huang et al., 2021). Although often interpreted as culturally relevant curriculum, a technologically relevant curriculum may also influence STEM student satisfaction, retention, and persistence in their field. Current STEM students use fewer digital tools, but demonstrate higher levels of role stress. This implies that limiting the use of creative technological applications for teaching and learning widens the gap between STEM students and academic success. Use of diverse technological applications may help meet demands for more interactive student-centered approaches to teaching (American Association for the Advancement of Science, 2011; Henderson et al., 2010).

Impact of New Technology

Similar to the observational study, role stress was responsive to technostress in the quasi-experimental portion of the study. As technostress increased among participants, so too did role stress. However, technostress, role stress, and productivity scores were not influenced by learning mode (RQ 3). Students using the new DTA did not demonstrate different levels of technostress, role stress, or productivity. This suggests that introduction of a new technology requirement does not impact current undergraduate students with predictable shifts in technostress, role stress, and productivity.

Implications

This study contributes to a growing body of research demonstrating a need to update instructional approaches, particularly for STEM undergraduates (American Association for the Advancement of Science, 2011; Henderson et al., 2010). Although technostress and productivity were not significant factors, role stress and course technology requirements were different between STEM and non-STEM students. The results have implications for the types of instructional approaches that students find most conducive to learning. For STEM students, technological applications for learning were more limited, and these students demonstrated higher rates of role stress. Consequently, this may contribute to disengagement and poor academic achievement, factors that influence STEM retention and persistence

(Seymour & Hewitt, 1997). In addition to calls for student-centered active learning in STEM classes, recommendations to improve instruction may also need to consider creative and diverse use of technology. Doing so will meet student expectations for educational technology (Gierdowski et al., 2020), which may improve engagement, retention, and persistence.

Limitations & Future Directions

Measuring differences in technostress, role stress, and productivity upon introduction of a new or unfamiliar application may be more effective using a repeated measures design in which variability between individuals is controlled. Baseline scores would be established prior to introduction of the unfamiliar technology. More importantly, exploring the connections between technostress, role stress, productivity, and learning outcomes would demonstrate the linkages between student technology use and academic performance.

Additional research is needed to better understand why STEM students are using fewer DTAs in their courses. The proportion of common tools and applications across STEM courses, combined with a course load dominated by STEM courses during a student's first year, may limit the diversity of technology a student experiences. Exploring the faculty perspective may also prove informative on this topic as well. Do STEM faculty avoid course technology more so than non-STEM faculty? If so, this would explain the quantitative difference in tools and applications between STEM and non-STEM students, but also reveal a new question: why are STEM faculty resistant to technological innovations for teaching and learning? Educational outcome expectations among K-12 teachers as a result of technology use declined post-pandemic (Francom, 2023), and a similar sentiment may be happening among higher education faculty.

As mentioned previously, technostress is not so much a stimulus or response, but more a process in which the presence of technology in one's environment requires a change in the behavior of an individual setting into motion psychological, physical, and behavior coping responses (Tarafdar et al., 2019). The response of the individual could be positive or negative. Here we present evidence of technostress variability among first-year undergraduates at an HBCU. Although higher levels of technostress were associated with higher levels of role stress, technostress was not related to productivity. Thus, undergraduate students can seemingly navigate technology-induced perturbations in role stress to maintain productivity, suggesting the presence of technostress eustress (Tarafdar et al., 2019). Additional research is needed to illuminate this topic, particularly understanding qualitatively how students engage with technostress and deploy reactive coping mechanisms to limit or control role stress and maintain productivity.

Conclusion

The objective of this study was to understand the relationships between course technology, major, technostress, role stress, and productivity to broaden the understanding of undergraduate STEM retention at an HBCU. Future work may yet benefit from a combined analysis of technostress, role stress, productivity, and retention. As this study demonstrates, technostress, role stress, and productivity are variable among first-year undergraduates, and may play important roles in students' decisions to persist or depart. Incorporating technostress, DTAs, major, role stress, and productivity within a logistical regression model may improve predictions regarding student retention. More importantly, such a model would identify students in need of support to increase their odds of persistence. Given the positive impact of HBCUs in producing STEM graduates, locating this future work at minority-serving institutions would disproportionately benefit efforts to diversify STEM leading to a more equitable future.

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Appendix

Technostress, Role Stress, and Productivity Survey

In the following questions, the term course technology refers to **all** the digital or virtual applications, software, tools, and websites you use to access resources, communicate, and complete assignments in your courses. Please rate how strongly you agree or disagree with the following statements.

Productivity

Course technology improves the quality of my course work.

Course technology helps me be more productive.

Course technology helps me learn more than would otherwise be possible.

Course technology helps me be a better student.

Role Stress

I often have more course work than I can handle.

I often work or study longer than the instructors suggest.

I often work on many assignments at the same time.

I never seem to have enough time to do my actual course work.

I often receive assignments without adequate resources and materials to complete them.

I often have to rely on classmates or outside resources to complete course assignments.

I often receive incomplete or unclear instructions from my instructors.

Technostress

Techno-overload

Course technology forces me to work much faster.

Course technology forces me to do more work than I can handle.

I am forced to change my study habits to adapt to course technology.

I have a higher course workload because of the increased technology complexity.

Techno-insecurity

I earn better grades due to course technology.

I have to constantly update my technological skills to avoid falling behind in coursework.

I am threatened by classmates with more advanced technology skills.

I do not share my knowledge with my classmates for fear of being wrong or embarrassed.

I feel there is less sharing of knowledge among classmates for fear of being wrong or embarrassed.

Techno-complexity

I do not know enough about the course technology to complete my work satisfactorily.

I need more time to understand how to use course technology.

I do not find enough time to study for classes and upgrade my technology skills.

Other students know more about the course technology than I do.

I often find the course technology too complex for me to understand and use.

Techno-uncertainty

There are always new developments in the technologies we use at this school.

I have to make constant changes to my computer/device software to complete coursework.

I have to make constant changes to my computer/device hardware to complete coursework.

I have to make frequent changes in how I access the internet to complete coursework.

Techno-invasion

I spend less time with my family and friends due to the course technology.

I have to be in touch with my course work even during school breaks due to the course technology.

I have to sacrifice downtime to keep current on the course technology.

I feel my personal life is being invaded by course technology.

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