WIP: Computation and Student Engagement in First-Year Engineering

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Abstract

Our WIP describes an exploratory quasi-experimental study to determine if first-year engineering students' academic motivation and engagement could be improved using *WebTA*. *WebTA* is a "code critiquer" to assist novice programmers in identifying issues in coding when first exposed to MATLAB. Utilizing Deci and Ryan's Self Determination Theory, we hypothesized that *WebTA* would contribute to students' needs for autonomy, relatedness, and competence, resulting in students who are more motivated and engaged, experience greater well-being and satisfaction, and develop stronger intrinsic motivation. Utilizing both the MUSIC Model of Motivation and Inventory, and a domain-specific motivation inventory, factor scores from both inventories were the dependent variables in a 2 X 2 design examining intervention (exposure to *WebTA*) and gender as independent variables. Significant interactions existed between intervention and gender on the MUSIC factor scores of empowerment, success, and caring. Women exposed to WebTA had significantly higher success, empowerment, and caring motivation than females in the control condition. In contrast, exposure to WebTA did not affect males' perceptions of motivation. Additionally, there was no significant difference between male and female factor scores in the Web TA condition, whereas females in the control condition had significantly lower factor scores than men. These findings suggest that WebTA can be a powerful tool in improving women's academic motivation and engagement, thus diminishing the gender gap in educational engagement.

Introduction

Our *Work in Progress* is a cross-departmental research project between the first-year engineering program, Engineering Fundamentals Department, College of Engineering and the Computer Science Department, College of Computing, both in Michigan Technological University. This report describes an exploratory study to determine if first-year engineering student academic motivation, and thus engagement, could be improved by using a computer assistant to aid in student introductory use of MATLAB. Our work is part of a larger project designed to develop further an application (*WebTA)*, which is an "auto critiquer tool" aimed at helping novice programmers identify and correct errors in coding when first exposed to university-level computer coding. *WebTA* was developed at Michigan Technological University by Dr. Leo Ureel and his research team in Computer Science. *WebTA* is currently in use experimentally in undergraduate classes in the MTU first-year engineering program (approximately 1,000 students per year).[1-3]

We expected that the real-time and specific feedback from *WebTA* to students would enhance their motivation to learn and use MATLAB. The current research focused specifically on *WebTA's* impact on student motivational factors, as would be predicted by Deci and Ryan's Self Determination Theory (SDT) [4]. SDT posits that humans inherently need autonomy, competency, and relatedness. When these needs are met, intrinsic (i.e., stemming from self) motivation increases. Intrinsic motivation drives academic motivation and engagement.

Autonomy is the need to feel in control of our actions and choices and, therefore, the ability to make decisions that align with our values and desires. People are more motivated, engaged, and fulfilled when autonomy is supported. Relatedness refers to the need to feel connected to others and experience a sense of belonging. It is about feeling valued, understood, and cared for by others personally and professionally. Competence is the need to feel capable, skilled, and effective in what we do. It's about mastering challenges, developing confidence, and experiencing personal growth. When the basic human needs of autonomy, relatedness, and competence are met, students are more motivated and engaged, experience greater well-being and satisfaction, and develop stronger intrinsic motivation [5-7].

Deci and Ryan [8] state that academic engagement is deeply tied to SDT, as students need autonomy, competence, and relatedness to stay motivated and engaged. Skinner and colleagues [9] conclude that engagement predicts academic achievement, school retention, and long-term learning success, key interests of engineering educators. Thus, our exploratory study sought to determine if increased motivation, and thus academic engagement, could be obtained by using the AI tutor for MATLAB with novice MATLAB users. We proposed that *WebTA* would positively impact students' autonomy by allowing them to control their actions. Secondly, by enabling students to master a new computational skill, *WebTA* would also enhance their need for relatedness. Gaining a skill necessary to their discipline may provide a sense of belonging, increasing the feeling of relatedness to the field and other students. Finally, we proposed that accessing WebTA would also support the need for competence. *WebTA* would lead to students who felt more effective, skilled, and capable. We hypothesized that students who had access to the automated *WebTA* tool would have enhanced motivation compared with students not having access to *WebTA*.

Research Methods

Participants

Our quasi-experimental design utilized a convenience sample from students enrolled in the First-Year Engineering program at a mid-sized university in the Midwest. The first semester course, from which the sample was drawn, has two pivotal goals: (1) developing a self-identity as an engineer and (2) developing strong engineering problem-solving skills. A key focus in the curricular design of the first-semester course is a threaded element focused on algorithmic thinking and computational competencies.

Students in this entry-level, first-year engineering course generally have their first introduction to algorithmic thinking and procedural programming using MATLAB. The classroom experience is designed to be a hands-on, active introduction that builds students' comprehension as they work through increasingly complex problems requiring complex computational tools. Based on an inverted delivery model, the classical explanatory content is delivered in short 5-10 minute condensed videos that students watch before attending a high-capacity studio session. All sections deliver coordinated content in a unified learning management system. Direct computational programming assignments and projects related to this study accounted for approximately 38% of the course grade.

Two hundred and seven (207) students enrolled in the First Year Engineering program consented to participate in the study, which was a 25% response rate from the 825 students invited to participate. Seven students who selected “other” or “choose not to respond” to an item inquiring about gender were not included in the analyses reported in this paper, as gender was one of the variables being assessed, and the group sizes were too small. Thus, our working sample consisted of 200 participants. Participants were enrolled in one of 7 sections of the first-semester first-year engineering program. Of these participants, a majority of the sample were male (n=153, 76.5%).

Variables

Historically, our research lab has adopted the MUSIC Inventory, based on Brett Jones’ MUSIC model of motivation, to assess first-year engineering student motivation.[10-13] The MUSIC model of motivation suggests five factors that impact academic motivation, including empowerment, usefulness, success, interest, and caring (see Table 1 for descriptions of each factor). An extensive list of researchers have validated the 19-item MUSIC Inventory. We also validated its 5-factor structure in our first-year student engineering program. The 5 MUSIC factors served as dependent variables and factors from an additional survey to assess self-efficacy for computational modeling in our engineering students [14]. We refer to this second survey as the “Motivation for Computational Modeling Survey” (MCMS). Table 1 lists the factors associated with the MCMS survey and their definitions. The 4 MCMS factors were also treated as dependent variables. All survey items directed respondents toward the course's MATLAB-specific assignments when responding.

Table 1. Key Dependent Variables as Factor Scores from Two Surveys

Factor Name	**Factor Description**
MUSIC Inventory	
e**M**powerment	Students feel empowered by the ability to have some control over their learning
Usefulness	Students understand why their learning is useful for their short or long-term goals.
Success	Students believe that if they put forth the effort, they can succeed
Interest	Students are interested in the content/instructional activities
Caring	Students believe that others in the classroom environment care about their learning and them as a person.
MCMS Survey	
Self-efficacy	Previous work on self-efficacy informs an individual’s judgment of his or her ability to execute a task within MATLAB [15].

Utility Value	An individual's judgment of the value of MATLAB and their successful use of MATLAB for their engineering career.
Self-regulation	An individual's ability to manage their learning environment effectively.
Self Assess. of Performance	Students rated their skill level as compared to other first-year engineering students in 3 task-specific areas of MATLAB.

Procedure

Human subjects approval was gained from the university IRB before data collection. All students from 7 sections of the first-year engineering course were offered a link to a Google form in a class period during the last week of the semester. They had completed the MATLAB work the week prior. They were told that extra credit for the class was available, regardless of whether they opted for their data to be included in the research project (data from the MUSIC inventory is also used annually for continuous improvement purposes within the first-year engineering program; the students could opt to take the surveys for that purpose only). A total of 248 students opened the link for the survey. Eleven students opened the link but chose not to take the survey. Thirty participants took the survey, but did not consent for their data to be used for research purposes. The remaining 207 students consented to the research. Seven (7) of these students chose not to include their gender, so their data was excluded from the statistical analyses.

The link provided to students was to a Google form, which included the consent and 19 MUSIC survey items combined to create 5 factor scores. Items were presented in random order. All MUSIC items were assessed using a 6-point Likert-type scale in which agreement was assessed (1 = strongly disagree; 6 = strongly agree). Factor scores were calculated as the mean of the individual items making up each factor. Higher factor scores represented higher perceived motivation. The MCMS survey assessed 16 items contributing to 4 factors on 6-point scales, except the comparison factor, which was measured on a 7-point scale. Higher values represented more agreement with items or a higher rated self-performance than peers.

Results

The 5 MUSIC and 4 MCMS factor scores were calculated as the mean of the individual items contributing to a factor. A multivariate General Linear Model (GLM) was conducted in SPSS to assess interactions and main effects of both *WebTA* and gender on the dependent variable factor scores associated with both surveys. The GLM in SPSS is a flexible analytic technique for use with both categorical and continuous variables. Both of our independent variables, exposure to *WebTA* intervention and gender, are categorical variables, each with two conditions, resulting in a 2 X 2 between subjects factorial design.

SPSS (version 29.0.2.0) was utilized for analyses with gender (male vs. female) and intervention (exposure to *WebTA*) as the independent factors, and all of the factor scores within a survey (MUSIC or MCMS) as dependent factors. A Levene's test for equality of variance resulted in equal variances within each factor on both surveys, except the MUSIC Usefulness factor. SPSS

does not correct for unequal sample sizes, which may have resulted in low estimates of power. Essentially, low power may result in findings of no significant differences - a Type 2 error. Given this WIP and the type of error possible (missing significant differences due to low power), we opted to consider results with this in mind rather than perform additional statistical tests at this time. Below, results per factor score are presented.

MUSIC Factor Results

All MUSIC Factors were entered into the GLM, resulting in an overall significant interaction between gender and WebTA exposure [F (7, 189) = 3.307, p = .002]. In addition, main effects of gender [F (7, 189) = 3.307] and *WebTA* exposure [F (7, 189) = 5.687] were significant with p < .001. Between subject analyses showed significant interactions for the MUSIC factors of empowerment, success and caring. In addition, a significant main effect of gender existed for the interest factor. The usefulness factor was not significantly different between groups. Figures 1 through 3 show the significant interactions across the MUSIC factor scores. Note that while scores ranged from 1 to 6, none of the means were below the scale's midpoint, so for clarity, all graphs start at a mean factor score rating of 3.

Empowerment Factor

As Figure 1 depicts, female students' empowerment was positively impacted by *WebTA* exposure [F(1) = 8.951, p = .003], while males' were not. Women's empowerment in the *WebTA* exposure condition was not different from men's (M=4.69 vs. M = 4.75). In the control condition, women had significantly lower (M=3.94) empowerment motivation than men (M=4.77).

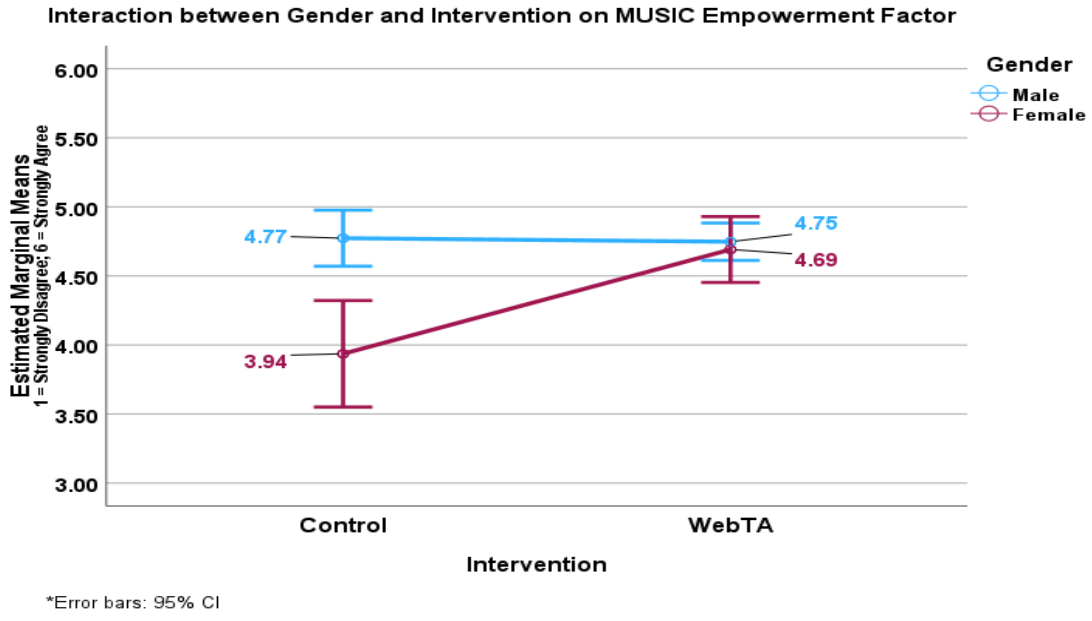

Figure 1. Interaction between Gender and *WebTA* Exposure condition on MUSIC Empowerment Factor Demonstrates the Positive Impact *WebTA* had on women's reported perception of empowerment.

Success Factor

Figure 2 displays the interaction between gender and *WebTA* exposure [F(1) = 4.851, p - .029], such that females who were exposed to *WebTA* had significantly higher success motivation (M = 4.96) than females in the control condition (M = 4.37). Exposure to *WebTA* had no effect on male's perception of success motivation. Additionally, there was no significant difference between male (M = 5.20) and female (M = 4.96) student success motivation for those exposed to WebTA.

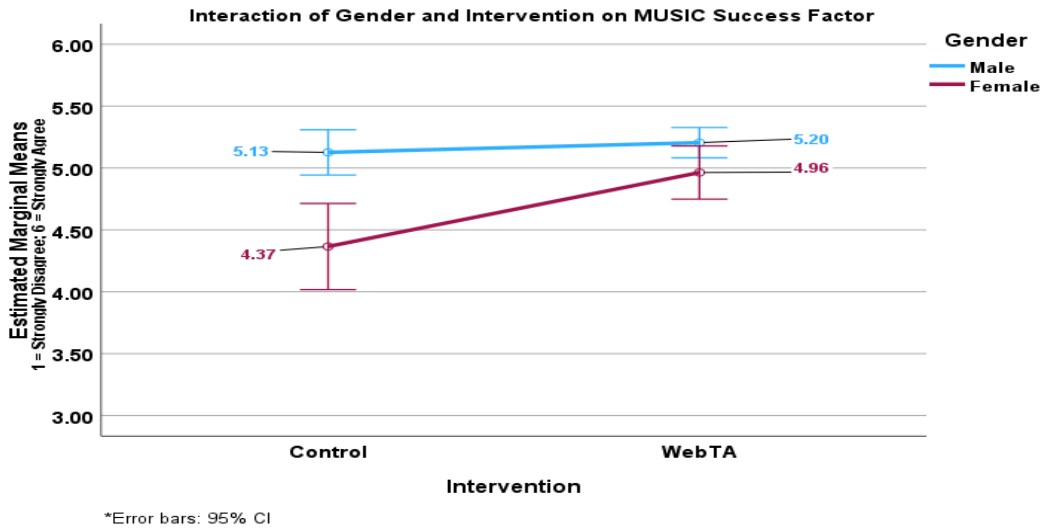

Figure 2. Interaction between Gender and *WebTA* Exposure on MUSIC Success Factor Demonstrates the Positive Impact of *WebTA* on women's reported perception of success.

Caring Factor

Figure 3 (below) depicts the interaction between gender and exposure to *WebTA* on the MUSIC caring factor [F(1) = 12.321, p < .001]. *WebTA* exposure positively impacted caring motivation for females (M = 5.64) as compared to females in the control condition (M = 5.00), but did not impact males' scores (control = 5.40, WebTA = 5.48). In addition, females (M = 5.64) exposed to *WebTA* did not differ in caring motivation from males (M = 5.48) exposed to *WebTA*.

Interest Factor

There was a significant main effect of gender on the MUSIC interest factor [F(1) = 4.269, p < .001]. Males ($M_{control}$ = 4.16; M_{WebTA} = 4.43) had a higher interest motivation than females ($M_{control}$ = 3.79; M_{WebTA} = 4.08), regardless of WebTA exposure.

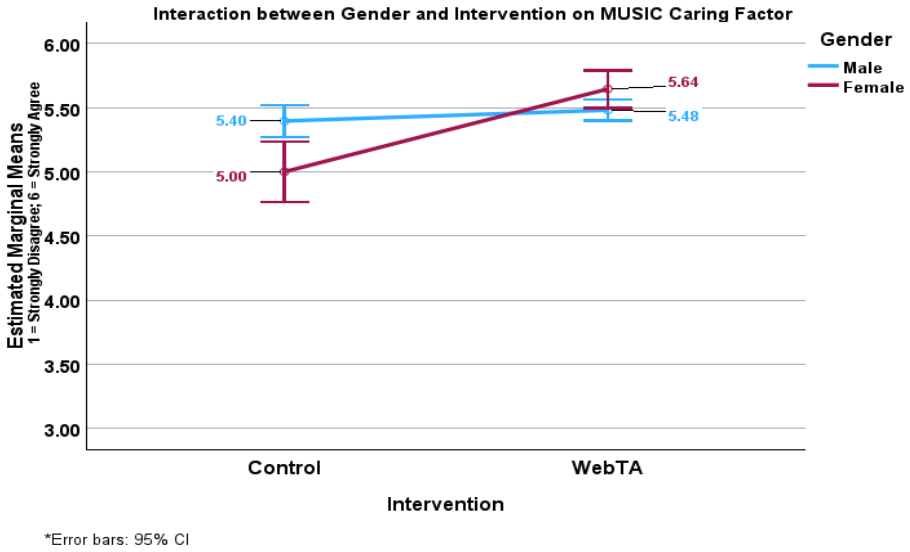

Figure 3. Interaction between Gender and *WebTA* Exposure on MUSIC Caring Factor Demonstrates Positive Impact of *WebTA* on women's perception of a Caring Environment.

MCMS Survey Factor Results

MCMS Factor scores (self-regulation, self-efficacy, utility value, and performance comparison) were entered into the GLM as dependent variables, with gender and *WebTA* exposure as independent variables. No significant interactions between gender and *WebTA* exposure existed [F (4, 192) = .825, p = .511]. A significant main effect of gender [F (4, 189) = 3.717, p = .006] was found. Between subjects analysis showed significant differences between genders on self-efficacy [F(1) = 10.459, p .001] and self-evaluation of performance [F(1) = 9.679, p = .002].

Regarding self-efficacy, male students had higher scores ($M_{control}$ = 4.82; M_{WebTA} = 4.83) as compared to female students ($M_{control}$ = 4.59; M_{WebTA} = 4.63) in both conditions. A similar main effect of gender existed in scores when students were asked to rate their MATLAB performance compared to peers. Mean scores were higher for men ($mean_{control}$ = 4.71; $mean_{WebTA}$ = 4.67) as compared to women ($M_{control}$ = 4.18; M_{WebTA} = 4.32). Recall that this scale ranged from 1 to 7.

Conclusion

The current study found an interaction between gender and *WebTA* presence on several of the MUSIC Inventory factor scores (caring, success, and empowerment). Each of these interactions had the same pattern of findings - exposure to *WebTA* increased motivation in women to a point equal to that of males. Further, *WebTA* did not impact male's motivation factor scores. Findings of a main effect of gender on 3 factor scores aligns with numerous previous studies which find that males rate the motivation items higher than do females.

Discussion

The findings from this study are exciting! The addition of an automated tutor (*WebTA*) that provides immediate and corrective feedback while novice engineering students are working to

learn coding concepts and methodology in MATLAB appears to have boosted females' motivation such that it was not distinguishable from males'. Specifically, women's perception of the following motivation scores as measured by the MUSIC instrument all resulted in women's scores as lower than men's in the control condition, but equal to men's scores in the *WebTA* condition:

- ➢ Empowerment, or having control over their learning;
- ➢ Success, or belief that success will come if they put forth the effort;
- ➢ Caring, or belief that others in the classroom environment care about their learning;

WebTA use did not affect men's scores on the motivation factors in this study.

SDT posits that humans will have higher intrinsic motivation if they feel autonomy, competency, and relatedness. We partially supported our initial hypothesis that *WebTA* would lead to increased motivation. The hypothesis was supported by female respondents only. It appears that males did not benefit from *WebTA* as we measured in this study. We are comfortable concluding that *WebTA* provides a feeling of autonomy, or control of their choices and actions, for females. It is clear to us that *WebTA* also provides support for the need for competency among female students. Perhaps the success gained with MATLAB use under the *WebTA* condition somehow allows female students to feel more "related" to others in engineering when they can successfully engage with tools of the trade. Simply improving and learning to use MATLAB could cause one to feel connected with engineers. In this sense, the need for relatedness is met.

As stated above, the support offered by *WebTA* provides increased motivation by meeting the needs for autonomy, competence, and relatedness in females only. Duckworth and colleagues [16, 17] raise the notion of self-control when suggesting that the mechanism for the common finding of higher grades for females is that they are more self-controlled. In this context, self-control would suggest that females are better at directing their focus and attention, directing their behavior toward achieving goals, and coping with emotions. [16] Females could count on the support of *WebTA* while learning MATLAB. We suggest that when women's need for self-control is met, they experience a boost in empowerment and believe they can be successful (both are MUSIC factors that were impacted by the interaction found in this study). Conversely, men generally don't have the same level of self-doubt and, thus, the same need for self-control. In addition, men likely don't have the same need for relatedness as females in an engineering curriculum. Therefore, the SDT quickly predicts the findings for women, and the assumption is that men have met the needs for autonomy, competence, and relatedness elsewhere.

The findings of this study require replication with a larger sample size and more balanced groups of males and females across conditions. We firmly believe that student engagement is the most critical factor in determining the value of courses for students, necessitating a robust and reliable metric for quantitatively assessing student engagement. This paper advances our broader goal by taking another important step toward establishing that the MUSIC survey can effectively measure student engagement in undergraduate engineering education. We aim to build a collaborative community that fosters the creation of a more extensive knowledge base and tests the self-control explanation we have proposed.

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