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Towards the Use of the MUSIC Inventory for Measuring Engineering Student Engagement

Dr. Susan L. Amato-Henderson, Michigan Technological University
Dr. Jon Sticklen, Michigan Technological University

Jon Sticklen is an Associate Professor with the Engineering Fundamentals Department (EF) and Affiliated Faculty with the Department of Cognitive and Learning Sciences (CLS). He served as Chair of EF from 2014-2020, leading a successful effort to design and implement a rejuvenated first-year engineering program serving approximately 1000 matriculating students per year. His research interests have focused on AI/Knowledge-based Systems: in particular, the ”task-specific” approach to knowledge elucidation and system building, function-based reasoning, explanation of reasoning. External support included NSF/CISE, DARPA, GE Aircraft, Boeing; Higher Education Research, Early STEM Education: in particular PBL, inverted classroom approaches, cooperative learning, distance education. External support included NSF/CISE, NSF/DUE. His current research foci include pedagogy of on-line learning, learning at the confluence of Human Factors, systems thinking mindset, and AI-based knowledge representation.

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Abstract

One of the "Grand Challenges in Engineering Education" is to engage students in their own learning. According to a past president of the National Academy of Engineering, engineering education must focus on the environment in which students learn. While the content is changing at a fantastic pace, facilitating a learning environment that fosters student ideas, inspiration, and empowerment is critical. We need students who are technically and creatively able to solve the challenges of tomorrow. The MUSIC Model of Academic Motivation was developed to help instructors apply motivation research to the design of instruction by providing an organizational framework of current motivation principles. A validated and reliable survey instrument, the MUSIC Inventory, was developed that was based on the MUSIC Model. Although not widely used in Engineering programs, this instrument may have increasing utility in coming years given the strong emphasis on student engagement. In Spring Semester 2022, we gave the MUSIC Inventory to 35 first-year engineering students at Michigan Technological University using a pre/post course method. As described in a forthcoming paper in Frontiers in Education 2022, the preceding semester we had a larger sample size (n = 300) but utilized a post-course only assessment to validate the motivation model factor analyses with our first-year students. .Early-term factor scores were significantly higher than late-term factor scores in the current study.Possible explanations of this finding are discussed. The larger purpose of the current study was to investigate the inter-relationships between the MUSIC Inventory factors. Specifically, we sought to further understand the role of the Caring factor in predicting student perceptions of empowerment. Empowerment is a key factor in student success. We report results based on our path analysis that increases our confidence in the use of the MUSIC Inventory in engineering programs, suggesting that the MUSIC Inventory may become a useful community tool for first-year engineering program and guide course design and alterations.

Introduction: The MUSIC Model for Academic Engagement and the MUSIC Inventory: Factors and Background

The MUSIC Model of Motivation research has produced a reliable and validated instrument for measuring student academic motivation with 5 factors; **eMpowerment**, **Usefulness**, **Success**, **Interest** and **Caring**. A brief review of each factor follows, including the specific theory of motivation that serves as the foundation for the factor. As the human motivation literature is vast, we will present only enough of the background literature to establish the foundation for our research hypotheses.

The M in MUSIC stands for **eMpowerment**, which refers to a student's perception that they, as the learner, have some level of control over their learning [1]. **Empowerment** is rooted in Deci and Ryan's self-determination theory [2] [3] [4] [5]. Specifically, motivation is thought to lie on a continuum of autonomy, ranging from completely autonomous (either intrinsic or extrinsic) to controlled. Either autonomous or controlled motivation is sufficient to initiate an activity, but autonomous motivation is required to maintain it. Therefore, factors that can increase autonomous motivation are beneficial within the academic environment. According to the theory of self-determination, autonomous motivation can be fostered when the following 3 basic psychological needs are met: autonomy (sense of control), competence (how much success one feels they have in the relevant environment), and relatedness (sense of social connection and support within the relevant environment). In sum, research regarding the self-determination theory would suggest that both perceived success and the sense of support in the form of a caring instructor would predict overall motivation or empowerment as described in the MUSIC model.

The **usefulness** factor in the MUSIC model suggests that motivation increases when students perceive the utility of their academic work toward earning their degree or their future career. The utility of their work can be in the short term, such as needing to pass a required course, or in the longer term, such as the value of learning information relevant to their future career or work. Work by Eccles and colleagues [2] on the expectancy-value theory of motivation serves as the foundation for the usefulness factor in the MUSIC Model. According to the expectancy value theory, students will put more effort into academic activities that they perceive will have value to them (i.e., usefulness) and at which they expect to succeed. For example, previous research by Jones

and colleagues found that the level of utility value students perceived could explain approximately half of the variance (51%) in their intention to pursue an engineering career. [6]. Based on this research, we expect that success and usefulness will both predict empowerment.

The **success** factor of the MUSIC inventory measures the perception that one can succeed in the relevant academic work if they put forth the effort [1]. Several different human motivation theories serve as the foundation for this factor. Bandura's now-classic self-efficacy theory [7], Covington's self-worth theory [8], goal orientation theory [9], and expectancy-value theory [10] all address achievement motivation and success/ competency. In fact, competency is now considered to be a basic human need [11]. Given the plethora of applications of Bandura's social-cognitive theory, we will focus our background on the foundation of the **success** factor as related to this work. The social cognitive theory [12] ties together motivation, achievement, and academic outcomes. Human agency is the result of interplay between one's beliefs, behaviors, and the environment. Bandura believed that one's success is more a function of belief in one's ability rather than actual ability, as one who doesn't't believe in their ability to succeed is not likely to attempt or engage in the activity. Research from social-cognitive theory, and Bandura's theory of self-efficacy [7] has shown that students who believe they can be successful are more inclined to try an activity, put more effort into the activity, are more resilient when faced with adversity, and persist when up against obstacles. Self-efficacy develops from 4 sources: 1.) previous mastery experience; 2.) vicarious experience; 3.) social persuasions from others; and 4.) somatic and emotional states (i.e., anxiety, stress, mood). Given these findings, we predict that students' perception of success and the perception of an instructor who cares about their success will predict the end of semester perception of empowerment in students.

The ***interest*** factor assesses the perception that both the material and instructional methods will be/are interesting [1] - both emotionally pleasing and one in which students' attention is drawn [13]. Research distinguishes between situational interest and individual interest, with individual interest being more long term and individually activated, whereas situational interest can be fleeting, and is stimulated by the environment. In terms of understanding academic interest as a motivator, researchers look to individual interest. As a foundation for the ***interest*** factor in the MUSIC model, we look to Hidi and Renninger's work [13]. They developed a model of 4 sequential phases in which individual interest can be activated when relevant knowledge and value of the content is combined with situational interest. According to Jones [1], very limited research has examined the development of interest in students. However, we do know that interest is positively correlated with attention, memory, comprehension, learning strategies, choice of major, and achievement [13]. Therefore, we predict that the ***interest*** factor will predict ***empowerment***.

The final factor measured by the MUSIC inventory is ***caring***, which measures the students' perception of their instructor as caring about their learning and personal well-being Many researchers believe that the establishment of caring, interpersonal relationships is a core human need (e.g., [4]). Terms often used interchangeably are sense of belonging, affiliation, attachment and connectedness. According to Jones [1], caring is more than just an interaction; it includes the belief that someone cares about you and your well-being. Instructor caring has been found to be a strong predictor of student learning [14]. Several theoretical models have placed a caring instructor as the central agent in student motivation and learning. For example, Bowlby's (1969) classic work investigating styles of attachment between children and their caregivers has also been used to examine the teacher/student relationship in elementary and preschool aged students [15]. Similar to Bowlby's findings with parents or caregivers, a secure attachment predicts many positive student outcomes such as willingness to explore, curiosity and resilience. Wentzel [16] applied a social support framework to investigate the effects of student/teacher relationships. Students will value and pursue academic and social goals that are perceived to be valued by teachers, especially when they perceive that their teacher provides clear direction on goals that should be achieved, assists them if needed, and provides emotional support and nurturing. Deci and Ryan's (2000) self-determination theory suggests that the student-teacher relationships are among the most influential in positive student outcomes [4]. In sum, the perception of having a caring teacher appears to be a positive, powerful force in numerous motivations within an academic context. We hypothesize that the ***caring*** factor will both directly predict empowerment, and indirectly predict it through the interest, usefulness and success factors.

Research Questions

The MUSIC model inventory was designed for use by instructors to examine student motivation, to encourage instructor reflection regarding classroom improvements to improve motivation, and to make data-informed decisions about curricular changes. Research using the inventory has been very applied in nature, as its use was intended. Our work has two purposes - to test for differences between early-term and late-term responses on the paired factors; and to take a step back to understand the underlying causal model of the factors together, as the various forms of motivation do not occur in isolation. Based upon the wealth of research touting the impacts of a caring instructor, we sought to understand a model that would demonstrate how a caring instructor can impact the other motivation factors with student empowerment as an end goal. In other words, we hypothesized that the perception of a caring instructor would predict empowerment both directly, and indirectly through the other MUSIC inventory factors.

To test for differences between the early and late-term scores, we utilized a paired-sample t-test. To understand and quantify the underlying relationships between the MUSIC inventory factors we used a path analysis model. Path analysis is a technique that allows representation of the underlying quantitative relationship among variables in a way that succinctly allows visualization of the model. Path analysis has been described as the historical "parent" of structural equation modeling (SEM) [17]. It was developed by biometrician Sewall Wright, who first used it to quantify the contributions of genetics vs. the environment on the coloring of guinea pigs.

Path analysis was originally conducted as a series of multiple regression statistical analyses used to estimate direct and indirect connections between variables. As a statistical method, path analysis allows the simultaneous comparison of both direct and indirect effects of multiple variables. One strength of this technique is that it forces researchers to consider the implications of a set of causal assumptions, theorizing the "A,B,C's" of somewhat messy causal relationships in the social sciences. While beneficial for supporting (or refuting) hypothesized models, path analysis does not determine if relationships are causal – one criticism of its use [18]. Stage and colleagues provide an excellent review of the use of path analyses within educational research through a review of the use and interpretations of the technique in articles published in the Journal of Educational Research from 1992 to 2002 [18]. We recommend anyone interested in utilizing path analysis as one step in their research should read this article. In summary, path analysis is a popular and useful technique for testing the validity of a theoretical model examining interrelationships between direct and indirect variables, however causal conclusions are ONLY theoretical.

Today, path analysis is also a specific application of SEM. Either the multiple regression procedure or SEM procedure is appropriate to use; we opted to utilize the multiple regression procedure. In path analysis, one starts with a visual diagram that represents the hypothesized model of relationships. Then, through a series of multiple regressions or through SEM, the model is tested for fit. The end goal of our work is to provide practitioners (instructors, curriculum designers, etc.) with a deeper understanding of the interrelationships between the various forms of motivation, and especially to understand the effects of caring instructors on student empowerment.

We hypothesized the following path diagram (see Figure 1). The caring factor is hypothesized to both directly and indirectly impact empowerment. Indirectly, we hypothesize that the caring factor will impact empowerment through interest, usefulness and success. All relationships are predicted to be positive, with arrows denoting assumed causal relations. Wider arrows denote that a larger effect is hypothesized. All variables with arrows pointing to them are termed endogenous variables. Each endogenous variable is explained by one or more variables (either endogenous or exogenous) and an error estimate (from those variables that may affect it but are not accounted for in our

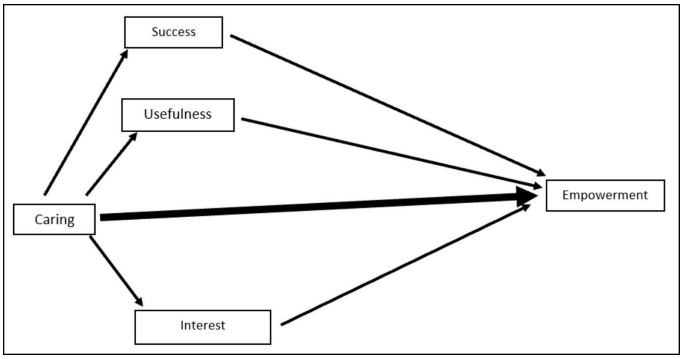

Figure 1: Hypothesized path diagram of MUSIC Model Factors

model). While empowerment in this model is correctly termed an endogenous variable, we also refer to it as our outcome variable as the goal is to understand how the other variables contribute to empowerment. In path analysis, all endogenous variables also serve as predicted variables from the exogenous variables that have an arrow directed to the "intermediate" variable.

Procedures

The Music Inventory [1] [19] was given in electronic format to students (n=35) enrolled in a first-year engineering course. Participating students took the survey twice; the first time was approximately one week after the semester began; the second during the last week of the semester. We refer to the first survey factors as "pre-factor name", and the factors from the second survey are referred to as "post-factor name" (for example, *pre- success* is the success factor from the early term survey, and *post-success* refers to the same factor as measured at the end of semester survey.) Both pre and post factor scores were calculated as instructed [19], and are the mean responses to the factor items as measured on a 6-point Likert-type scale (1 = strongly disagree; 6 = strongly agree).

Results and Discussion

Means and standard deviations for each of the early-term and late-term factors are shown in Table 1. Differences between the early-term factor and late-term paired factor scores were assessed using repeated-measures t-tests with alpha = .05. Significant differences pre to post are flagged in Table 1, using an alpha level of .05. All factor pairs, with the exception of usefulness, were significantly lower at the end of the semester as compared to student responses in the early semester. The pair of usefulness factors did not differ significantly (p = .087).In addition, Table 1 also provides the correlations between factor pairs. All were significantly correlated at an alpha level of .05.

Table 1. Music Model Inventory Pre and Post Factors in a First-Year Engineering Course

Factor	Pairs	Mean	Std. Deviation	Correlation
Pair 1*	Pre-Empowerment	4.1867	1.0451	.686#
	Post-Empowerment	3.7733	0.95518	
Pair 2	Pre-Usefulness	4.2267	1.2668	.665#
	Post Usefulness	3.9800	1.04697	
Pair 3*	Pre-Success	4.8833	0.9371	.634#
	Post-Success	4.2667	1.4034	
Pair 4*	Pre-Interest	3.8667	1.2109	.522#
	Post-Interest	3.1889	1.30775	
Pair 5*	Pre-Caring	4.9944	1.10509	.755#
	Post-Caring	4.2833	1.13474	

*significant difference between factors at alpha = .05

#significant correlation exists at alpha = .05

A series of multiple linear regression models were calculated for each of the endogenous variables, with the standardized beta weights (i.e., standardized regression coefficients) serving as the measure of prediction in the output path diagram The results of the path analysis with predicted extraneous variability not accounted for by the model (presented in circles with an arrow leading to each endogenous variable) are presented below in Figure 2.

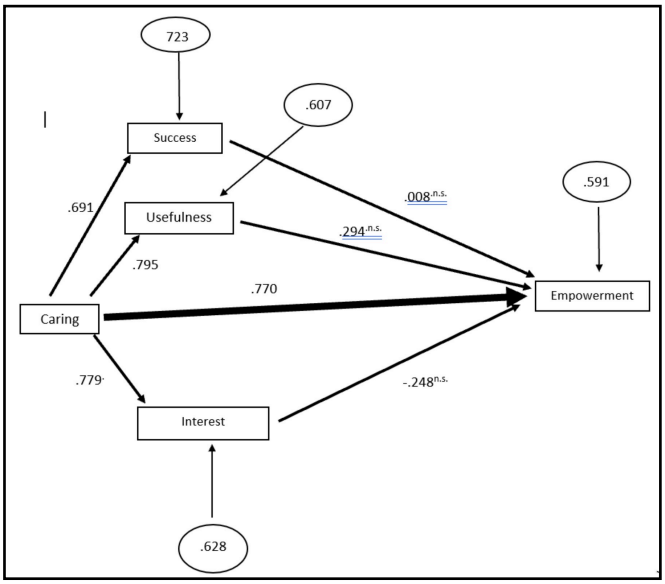

Figure 2. Output Path Model of Music Factors Predicting Empowerment

Next, we calculate the direct and indirect effects of caring on empowerment by multiplying the regression coefficients for each path (calculate the product of the path coefficients), then summing the weights. Direct and indirect effects are presented in Table 2 (below).

The sum of the direct and indirect paths suggests that this model predicts 40.9% of the variability in empowerment (1 - extraneous variability, or 1 - .591). However, the indirect paths of caring to empowerment were not significant coefficients in the regression model. In other words, they did not account for a significant amount of the variability

in empowerment given the weight of the direct effect of caring. To view (and understand) this differently, we calculated a path model in which no indirect paths were included; one in which each of the other MUSIC factors is entered as a direct predictor of empowerment. Figure 3 is the output path model that results. Similar to the previous model (shown in Figure 1), the contributions of the other variables are considered by each individual regression coefficient. Note the only difference between the hypothesized output model (Table 2) and this new model (Table 3) is the sum of individual direct weights and the ability to calculate total variance accounted for by the model (as indicated by adjusted R2). Adjusted R2 = .651, indicating that 65.1% of the variability in empowerment is accounted for by this model. Total of the path weights for this model, examining only direct effects, is .824 (an increase over the sum of the hypothesized model weights of .007)

Table 2. Output Path Model Explanatory Value of Paths in Predicting Empowerment

Path	Effect Type	Weight
Caring → Empowerment	Direct	.770
Caring → Interest → Empowerment	Indirect	-.193
Caring → Usefulness → Empowerment	Indirect	.234
Caring → Success → Empowerment	Indirect	.006
Sum of Weights		.817

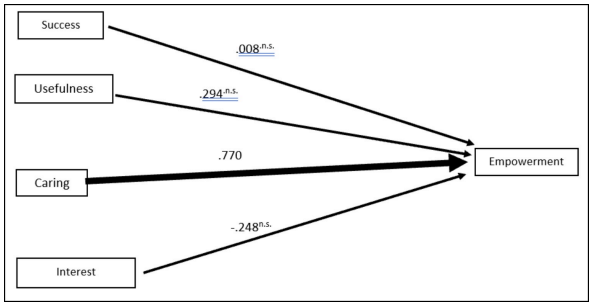

Figure 3. Alternate Path Analysis Output Model

Conclusions and Next Steps

We examined changes in student motivation in a first-year engineering course between an early-term survey and late-term survey using the MUSIC Inventory. Five motivation factor scores were calculated for both surveys, and were compared for differences using a paired-samples t-test (alpha = .05). All factors significantly decreased from the early-term to the late-term with the exception of the usefulness factor. Three possible conclusions explain this finding: 1.) the course negatively affected motivation levels; 2.) students overestimate their motivation at the beginning of the semester, or 3.) this small sample of students may not reflect what would happen in the population (the effects are spurious). The early-term survey was given during the first week of the semester, and as such can be considered as a student's estimate of what levels of motivation they will experience in the class. The late-term survey was given during the last week of class and can be considered measures of the actual motivational levels students experienced in the course. In this sense, the conclusion would be that students overestimate their motivation levels when a class starts. To test the reliability of our findings regarding early and late-term differences, we plan to include all first-year engineering students in a future iteration of this project, resulting in a sample size estimated to be well over 300 students.

Table 3: Total of Direct Effects of MUSIC Model

Variable Path	Effect Type	Weight
Caring → Empowerment	Direct	.770
Interest → Empowerment	Direct	-.248
Usefulness → Empowerment	Direct	.294
Success → Empowerment	Direct	.008
Sum of weights		.824

We also conducted a path analysis to test the hypothesized impact of a *caring instructor* on the other motivation factors. **We hypothesized that the caring factor would significantly predict student empowerment through** model in which caring had both a direct effect on empowerment, and indirect effects on empowerment through the success, interest, and usefulness factor scores. In other words, we believed that success, interest, and usefulness would be significantly impacted by students' perceptions that their instructor cared about their academic success and personal well-being. This model resulted in a total weight of direct and indirect paths of .817 on empowerment. However, while caring appears to significantly affect success, interest, and usefulness, the indirect effects were minimized by the very large direct effect of caring on empowerment. We presented an alternate output path analysis in which only the direct effects of caring, success, interest, and usefulness on empowerment were examined. This model resulted in a slightly higher total weight of direct paths (.824 versus .817). We believe that the benefits of the first model show the overall importance of the **caring** motivation factor on all of the other factors, as it has large beta weights predicting each of the other variables. The second model is more succinct (i.e., simpler), but does not demonstrate the multifaceted nature of caring's impact on

the other motivational factors. Given the small total size of estimate differences (.07), we suggest the first model be used to guide future research as it demonstrates that various forms of motivation do not occur in isolation of one another.

Future plans include replication of the path analysis using a larger sample size. In addition, further research on our finding that motivation scores dropped from the early to late-semester assessment is warranted. Understanding if this drop is due to an overestimate of motivation in the early-semester assessment, or an actual decline in motivation during the course will be important for those interpreting the results of a pre/post survey methodology. Finally, we will continue to examine the role of caring motivation on student empowerment. While an experimental design cannot ethically be carried out in an actual course, we plan to conduct an experimental design in which we ask participants to rate MUSIC inventory items as if they were a student enrolled in a given course).The independent variable manipulation would be showing participants one of three videos in which instructor caring is manipulated to be low, average or high. While not representative of an actual course, combined with the current results this method could inform our understanding of the importance of caring on the other forms of motivation.

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