A Study on the Pre-Service Teachers' STEM Interdisciplinary Teaching Intention

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BACKGROUND

This study applies the theory of planned behavior as a basis and references relevant literature to suggest an extension of variables for discussing the impact of knowledge, values, subjective norms, perceived behavioral controls, and attitudes on the behavioral intentions of interdisciplinary science, technology, engineering, and mathematics (STEM) education among Taiwanese pre-service science teachers.

PURPOSE

This study aims to explore the impact of Taiwanese pre-service teachers' knowledge, values, subjective norms, perceived behavioral controls, and attitudes toward interdisciplinary STEM teaching, and the impact of said characteristics on the behavioral intentions of interdisciplinary STEM teaching.

METHOD

Self-designed questionnaires were implemented to conduct surveys on the "behavioral intentions of pre-service science teachers engaging in interdisciplinary STEM education," and a total of 139 valid samples were collected. Data were tested using descriptive statistics, path analysis, and variance analysis.

RESULTS

Science teachers' reactions toward positive public support and negative objection (subjective norms), in addition to one's ability to control resources and resolve difficulties related to STEM interdisciplinary teaching (perceived behavioral controls), are two key factors affecting interdisciplinary STEM teaching behavioral intentions, which also serve as a reference for the future promotion of its practice.

CONCLUSIONS

The results revealed that, in terms of direct effect, the higher an individual's perceived behavioral control and subjective norms, the stronger his/her interdisciplinary STEM teaching intention. In terms of indirect effect, higher attitudes or knowledge were indicative of better subjective norms or perceived behavioral controls, resulting in a higher interdisciplinary STEM teaching intention. Additionally, greater knowledge in interdisciplinary STEM education did not lead to better attitudes, although better perceived behavioral control resulted in stronger interdisciplinary STEM teaching intention.

KEYWORDS

pre-service teachers, STEM, theory of planned behavior.

A Study on the STEM Interdisciplinary Teaching Intention of Pre-Service Teachers

Introduction

The integrated education of Science, Technology, Engineering, and Mathematics (STEM) has been discussed widely in recent years. Thus, high quality STEM education is key to career success in the twenty-first century (Bybee, 2010). Additionally, the United States has invested more in STEM education to remain competitive in the global economy (Chen, 2009). Although the significance and current objectives of STEM education are not clearly defined (Bybee, 2013), STEM education has been integrated into the critical planning of American scientific and technological literacy standards (International Technology Education Association, 2007; National Research Council, 2012). Furthermore, many scholars hoping to establish a mechanism for integrating STEM fields and training STEM talents have become involved in related research (Nicholls, Wolfe, Besterfield-Sacre, Shuman, & Larpkiattaworn, 2007; Nicholls, Wolfe, Besterfield-Sacre, & Shuman, 2010; Nathan, Srisurichan, Walkington, Wolfgram, Williams, & Alibali, 2013).

Although scholars in different fields have varying opinions concerning the objectives of STEM education, this study adopts Sanders' views (2012) and considers it an interdisciplinary teaching method. Through this teaching method, students are trained to develop integration capabilities in science, technology, mathematics, and engineering to solve problems related to a shortage of practical teaching in traditional theory-based education. Bybee (2013) further suggests that interdisciplinary STEM teaching methods focus on global issues, such as climate change and energy policies. Activities in science, technology, and engineering should emphasize the importance of design and production capacity, especially at the design stage. Interdisciplinary STEM teaching methods should also focus on theory-based design to effectively help students integrate scientific, technological, engineering, and mathematical knowledge. Therefore, greater attention must be given to adopting STEM interdisciplinary teaching methods effectively and determining how teachers should embody and learn to achieve this goal (Vescio, Ross, & Adams, 2008). For example, in the United States improving teachers' interdisciplinary STEM teaching abilities is emphasized in the implementation of STEM education plans in both elementary and secondary schools (Kuenzi, 2008).

Darling-Hammond and McLaughlin (1995) once proposed that in educational reform, teachers must conduct self-reflection, attempt to reconstruct the roles played by their students, and use different approaches to guide students. However, studies examining the behavioral factors affecting teachers' decision to implement interdisciplinary STEM teaching are sparse. Thus, the planning of teacher or in-service teacher training courses that effectively develop interdisciplinary STEM teaching skills is an important topic for future studies. To predict and understand human behavior, Ajzen (1985) proposed a theory of planned behavior emphasizing how individuals' behavioral intentions shape their behavior. Ajzen maintained that behavioral intentions are based on attitudes, subject norms, and perceived behavioral controls—factors that are also affected by external variables. In accordance with Ajzen's theory, this study focuses on teachers' knowledge, values, subjective norms, perceived behavioral controls, and attitudes toward interdisciplinary STEM teaching (in addition to the effect of those attributes on behavioral intentions) to provide a helpful resource for planning future teacher training and in-service training courses.

This study first aims to study the impact of Taiwanese pre-service teachers' knowledge, values, subjective norms, perceived behavioral controls, and attitudes toward interdisciplinary STEM teaching, and the impact of said characteristics on the behavioral intentions of interdisciplinary STEM teaching. Secondly, it intends to explore whether a relationship exists between Taiwanese pre-service teachers of varying backgrounds and their interdisciplinary STEM teaching knowledge, values, subjective norms, perceived behavioral controls, attitudes, and behavioral intentions.

Methods

Research Framework

The theory of planned behavior may serve as a behavioral prediction model to envisage educators' behavioral intentions for interdisciplinary STEM teaching (Ajzen, 1985; Ajzen & Madden, 1986). Here, intention refers to an individual's evaluation of a particular behavior's result, which is greatly influenced by public subjective norms and control beliefs. According to a review of literature, this study proposes that rather than retaining the original variables of interdisciplinary STEM teaching theory, external variable extensions should take place in studies involving the knowledge and values of interdisciplinary STEM teaching (Figure 1) to determine whether knowledge, values, subjective norms, perceived behavioral controls, and attitudes towards the practice affect its behavioral intentions. The operational definition of each variable is provided in Table 1.

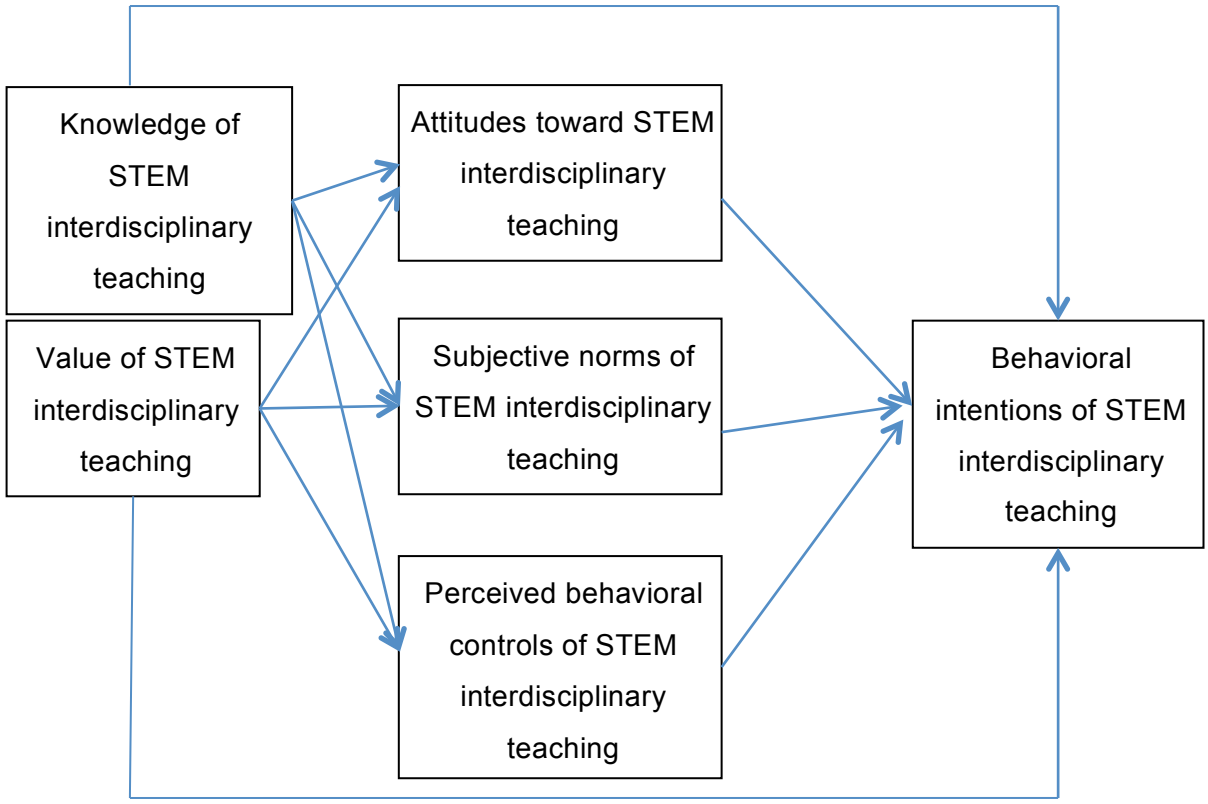

Figure 1: Research framework

Table 1: Operational definitions of variables in this study

Variable	Operational definition
Knowledge	The level of an individual's understanding of science, technology, engineering, and mathematics.
Values	Changes in an individual's set of values under interdisciplinary STEM teaching, and how these results affect one's self-evaluation and evaluation of students' remarks (both positive and negative) concerning its practice.
Attitudes	An individual's interest in interdisciplinary STEM teaching and whether they will apply or discuss topics related to it.
Subjective norms	The individual impressions of important reference groups regarding their support or opposition to the implementation of interdisciplinary STEM teaching, in addition to their degree of compliance toward said norms.
Perceived behavioral controls	Degree of difficulty faced by an individual in choosing to adopt interdisciplinary STEM teaching, and whether he/she can control relevant resources and self-adjust while doing so.

Behavioral intentions	The intent and likelihood of an individual to adopt interdisciplinary STEM teaching in their future teaching career.

Samples

The subjects in this study included 144 pre-service junior high school science teachers. Three main educational institutions exist for the training of pre-service science teachers. A normal university located in northern Taiwan was selected as the main research target. Questionnaires used for this study were designed to evaluate teachers' behavioral intentions. The study began in the first semester (between September 30, 2013 and January 2014); 61 pre-service science teachers participated during this period, and 60 valid questionnaires were returned. For the second semester (between February and June 2014), 83 pre-service science teachers participated; 79 valid questionnaires were received from this group, which was 43.2% and 56.8% male and female respectively. The participants' disciplines included six majors as listed in table 2.

Table 2: Sample of descriptive statistics

Population variables	Name	Number	Percentage
Gender	Male	60	43.2%
	Female	79	56.8%
Major	Physics	16	11.5%
	Chemistry	11	7.9%
	Life science	34	24.5%
	Earth science	13	9.4%
	Technology	47	33.8%
	Other	18	12.9%

Note: "Other" comprises instructors of non-scientific disciplines interested in teaching science, who were consequently included in the study.

Implementation

This study focused on the behavioral intentions of Taiwanese pre-service science instructors toward the implementation of interdisciplinary STEM teaching. Since experts in different disciplines may possess varying opinions concerning STEM education (Bybee, 2013), a series of lab activities were conducted to help pre-service instructors implement interdisciplinary STEM teaching. For example, a semester (three hours weekly for eighteen weeks) was devoted to providing detailed descriptions of STEM courses, allowing participants to develop an in-depth understanding of the practice's purposes and values. Besides, other activities (e.g. balloon cars, mousetrap cars, a hand throwing machine, sorting devices, and bridges) allowed educators to personally experience interdisciplinary STEM teaching.

Participants were required to follow the design and production procedures for each activity, and implement STEM knowledge during all procedures to ensure the integration of theory and practice. After students completed these activities, researchers issued their versions of the interdisciplinary STEM teaching intention questionnaires, and asked teachers to describe their behavioral intentions toward its implementation. To accommodate teachers majoring in physics, chemistry, life science, and earth science, the study spanned between September 2013 and June 2014; courses were conducted twice to ensure that diverse opinions concerning interdisciplinary STEM teaching behavioral intentions among pre-service science teachers majoring in different fields were collected.

Instrument

The study's measurement tools were developed according to Ajzen's (1985) theory of planned behavior, which served as the basis for each variable's operational definition (Table 1); seven-point scale measurements were applied in drafting the questionnaires in agreement with relevant literature. The questionnaires included four knowledge-related questions, five concerning values, six regarding attitudes, six pertaining to subjective norms, five related to perceived behavioral controls, and five on behavioral intentions. To ensure the questionnaires' appropriateness, four professors in relevant fields and four junior high school teachers were invited to review their content; the questionnaires were later modified

accordingly.

Exploratory factor analysis was performed to review the categories and content of questionnaire factors, and to delete questions or adjust question topics appropriately. Main factor analysis was used to locate factors with eigenvalues greater than 1, coupled with Promax rotation to maximize differences in factor loadings. After two factor analysis, questions that did not match factor types or whose factor loadings were less than 0.3 were removed. During the third factor analysis, six main factors were extracted with factor loadings greater than 0.4 in each question (while maintaining the original factor names). Finally, Cronbach's α reliability analysis was conducted with 0.79 for knowledge, 0.91 for values, 0.85 for attitudes, 0.80 for subjective norms, 0.88 for perceived behavioral controls, 0.86 for behavioral intentions, and an overall internal consistency coefficient of 0.94—reaching the proper reliability level according to Devellis (2003).

Data Analysis

Owing to a sample size of less than 200 and variables belonging to formative indicators, a theoretical model was constructed and tested using a Partial Least Squares (PLS) approach to Structural Equation Models, also known as PLS Path Modeling (PLS-PM). PLS-PM is a component-based estimation method, which utilizes an iterative algorithm that separately resolves out the blocks of a measurement model and estimates the path coefficients in the structural model (Vinzi, Trinchera, & Amato, 2010; Tenenhaus, 2008). Therefore, PLS-PM was selected to examine the path coefficients of pre-service teachers' STEM interdisciplinary teaching intention models, and to analyze the effects of latent variables in the model. To date, the model validation process comprises parameter inference, where the significance of estimated parameters is tested (Chin, 1998). However, models with significant bootstrap parameter estimates were used in this study to explore path coefficients among latent variables in the structural model (Chin, 2009).

The data collected in the 139 questionnaires were analyzed using single-factor multivariate analysis of variance (MANOVA) to determine whether changes in independent variables, such as gender, age, and major, exhibited significant effects on STEM interdisciplinary teaching intentions. When the statistics reached a significant level, the Scheffe method was used as a post-test to compare differences between independent variables.

A Theoretical Model of Pre-Service Teachers' STEM Interdisciplinary Teaching Intentions

To study the behavioral intention model of pre-service instructors in relation to interdisciplinary STEM teaching, the data of six variables were analyzed. The six variables' correlation coefficients are listed in Table 3; the correlations between all variables were significant. Among the lowest correlation coefficients for knowledge and attitude, no direct relationship existed between pre-service science teachers' knowledge of STEM and their attitudes toward interdisciplinary teaching; however, values, subjective norms, and perceived behavioral controls may play important roles in establishing STEM interdisciplinary teaching behavioral intentions.

Table 3: Summary of the correlation coefficients of variables (*N*=139)

	Knowledge	Values	Attitudes	Subject norms	Perceived behavioral controls	Behavioral intentions
Knowledge	1					
Values	.33***	1				
Attitudes	.30***	.65***	1			
Subjective norms	.32***	.59***	.58***	1		
Perceived behavioral controls	.43***	.48***	.39***	.51***	1	
Behavioral	.37***	.72***	.58***	.68***	.68***	1

intentions						
M/SD	5.06/.93	5.64/.84	5.58/.78	5.29/.80	4.78/.93	5.16/.84

Note 1: *p<.05, **p<.01, ***p<.001.
Note 2: The questionnaire was designed on a seven-point scale.

This study was based on the theory of planned behavior, in addition to relevant literature promoting the interdisciplinary STEM teaching behavioral intentional model for pre-service science teachers. Partial least squares (PLS) regression was used to test the model's appropriateness; since PLS does not provide a p value, the bootstrap method was used to calculate the t value. Z distribution was applied as a standard since the study's sample size exceeded 120 participants, suggesting a level of significance with t values greater than 1.96. One hundred samples were extracted from a total of 139 based on the bootstrap method, which draws samples from a pool randomly and returns them before the next draw. This was repeated until the hundredth sample was extracted. These 100 samples were then used to conduct analysis and obtain a set of estimated results. This operation was repeated 200 times to obtain a distribution of estimated results, and subsequently a t value. The bootstrap method results are shown in Table 4.

Table 4: Bootstrap data analysis results

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	Standard Error (STERR)	T Statistics (|O/STERR|)
attitudes-> behavioral intentions	0.05	0.05	0.06	0.06	0.78
knowledge-> attitudes	0.10	0.10	0.08	0.08	1.30
knowledge-> behavioral intentions	0.00	-0.01	0.06	0.06	0.04
knowledge-> perceived behavior controls	0.30	0.31	0.10	0.10	2.84*
knowledge-> subjective norms	0.14	0.15	0.09	0.09	1.48
perceived behavior controls-> behavior intentions	0.36	0.37	0.09	0.09	3.77*
subjective norms-> behavior intentions	0.26	0.25	0.09	0.09	3.00*
values->attitudes	0.62	0.62	0.08	0.08	7.83*
values-> behavioral intentions	0.36	0.36	0.10	0.10	3.54*

values-> perceived behavior controls	0.40	0.40	0.07	0.07	5.72*
values-> subjective norms	0.58	0.57	0.09	0.09	6.23*

According to PLS data analysis, behavioral intentions, attitudes, subjective norms, and perceived behavioral controls were explained effectively. The explanation variances for behavioral intentions, attitudes, subjective norms, and perceived behavioral controls were 0.73, 0.44, 0.41, and 0.33, respectively. Subjective norms and perceived behavioral controls were mediator variables. Both knowledge and values are capable of affecting interdisciplinary STEM teaching behavioral intentions through the mediator variables. A flow-chart illustrating the model's estimated results is provided in Figure 2, from which several points concerning pre-service science teachers' interdisciplinary STEM teaching behavioral intentions can be derived. First, participants' interdisciplinary STEM teaching behavioral intentions were closely affected by their subjective norms, perceived behavioral controls, and values. These attitudinal variables did not affect behavioral intentions directly, although it could affect teachers' behavioral intentions through the mediation of subjective norms. Second, participants' STEM knowledge did not directly affect behavioral intentions, although it could do so through perceived behavioral controls. Finally, the impact of values on behavioral intentions might also depend on subjective norms and perceived behavioral controls.

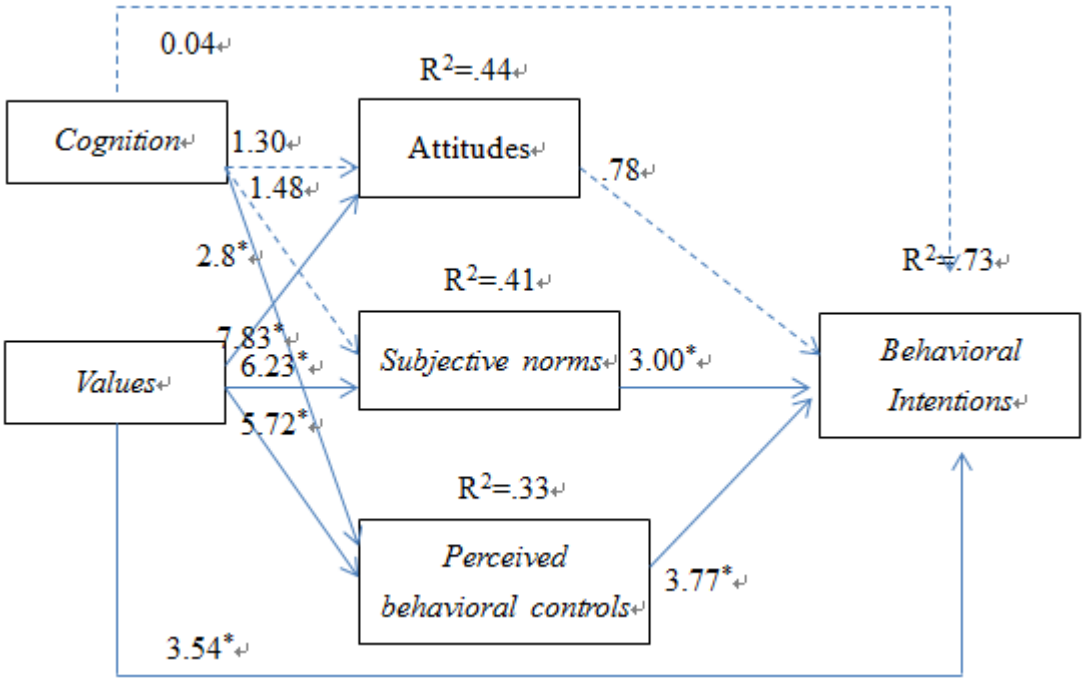

Figure 2: Behavioral intentions route of pre-service teachers' interdisciplinary STEM teaching intentions
Note: *p<.05, **p<.01, ***p<.001.

According to the results above, science teachers' reactions toward positive public support and negative objection (subjective norms), in addition to one's ability to control resources and resolve difficulties related to STEM interdisciplinary teaching (perceived behavioral controls), are two key factors affecting interdisciplinary STEM teaching behavioral intentions, which also serve as a reference for the future promotion of its practice.

Conclusion and Implications

The theory of planned behavior was employed in designing questionnaires examining the interdisciplinary STM teaching intentions of Taiwanese pre-service teachers. In terms of direct effects, the higher an individual's perceived behavioral control and/or subjective norms, the stronger their interdisciplinary STEM teaching behavioral intentions. As for indirect effects, the greater an individual's attitude or knowledge, the better his/her subjective norms or perceived behavioral controls, resulting in stronger interdisciplinary STEM teaching behavioral intentions. Besides, greater knowledge of interdisciplinary STEM teaching does not presuppose better attitudes, although better perceived behavioral controls can lead to stronger interdisciplinary STEM teaching behavioral intentions. In short, for future advancement it is critical that instructors understand the potential value of interdisciplinary STEM teaching. Furthermore, it is important that pre-service science teachers be trained to effectively manage available resources when implementing interdisciplinary STEM teaching. Finally, educational authorities and school administrators should support educators in pursuing interdisciplinary STEM teaching, and avoid an examination-based culture, which inevitably affects the practice's implementation.

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