Korean Students' Attitudes toward STEM Project-Based Learning and Major Selection[*]

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Abstract

The trend of avoiding science, technology, engineering, and mathematics (STEM) majors has persisted resulting in a lack of professionals in STEM fields. Further, the current STEM education system in Korea does not meet domestic demands for STEM labor. To discover an educational approach encouraging students to choose STEM majors at the post-secondary level, the current study employed a survey instrument investigating students' attitudes toward STEM project based learning (PBL), and examined the relationships between these attitudes and intent to pursue a STEM major. A model depicting the relationships was proposed, and the structure of the model was verified using structural equation modeling. Additionally, a mediation relationship on the model was investigated and tested. Finally, the gender difference on the paths of the structural model was analyzed using multiple-group analysis. The results indicated that students who were positive toward PBL components (i.e., technology based learning, self-regulated learning, and hands-on activities) except "collaborative learning" were more likely to have the intent to pursue a STEM PBL. In addition, belief in STEM majors' benefit played a role as a mediator. The findings of this study help secondary teachers guide students through major and job selection by integrating PBL into mathematics and science classrooms.

Keywords

Career choice • PBL • Structural equation modeling • Multiple-group analysis • Korean student

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Korean society is currently facing challenges in science, technology, engineering, and mathematics (STEM) fields. First, a trend toward avoiding STEM majors, which indicates the majors relating to science, technology, engineering, and mathematics, has persisted for the last 15 years; this has caused workforce deficits in STEM fields. Due to the lack of STEM professionals, many small- and medium-sized businesses requiring STEM knowledge and skills in Korea have been unable to fill open positions (Shim, 2012). Another difficulty that Korean society has confronted is that promising high school students have been more likely to select majors in medicine and medical science rather than pure mathematics or science majors (Choi & Lee, 2008). As STEM fields are pivotal for vitalizing the national economy, it is necessary to ensure that high-quality students with great leadership potential select STEM professions. At present, however, many students with an aptitude for STEM majors are choosing to pursue majors in other fields. This is likely to cause severe problems not only in the present but also in the future (Choi & Lee, 2008).

The current STEM education system in Korea does not meet domestic demands for STEM labor. International test results (e.g., from the Programme for International Student Assessment [PISA] and the Trends in International Mathematics and Science Study [TIMSS]) have indicated that Korean students have less positive attitudes toward learning mathematics and science compared with students in other countries, although Korean students have ranked within the top five participating countries in terms of academic achievement in these fields. Studies pointed out that Korean students' negative attitudes toward learning mathematics and science derive from the traditional instructions commonly implemented in Korean classrooms and focusing on an algorithmic approach, which indicates an instructional approach leading students to simply memorize mathematics algorithms and not enough to make sense of the background processes (Cho & Kim, 2013; Kim, 2012). With the decline of students' interest in mathematics and science and the increase in negative attitudes toward learning mathematics and science, fewer students are choosing STEM majors at the college level.

To encourage students to choose STEM majors at the post-secondary level, it is important to establish learning environments that stimulate student interest in STEM majors (Lent, Sheu, Gloster, & Wilkins, 2010; Wang, 2013). According to the social cognitive career theory (SCCT; Bandura, 1986; Lent et al., 2010), students' interests influence their academic and career choices, as do self-efficacy beliefs, outcome expectations, environmental supports and barriers, and choice actions. In other words, learning environments that boost student interest may affect students' academic intentions and, in turn, what they finally decide regarding a major. Therefore, it is critical for educators and policymakers to realize that major selection can be guided by school-based educational efforts.

Project-based learning (PBL) is one instructional approach that has been commonly used in STEM classrooms. Studies have examined the positive impacts of PBL on student interest in STEM disciplines (Baran & Maskan, 2010; Domínguez & Jaime, 2010; Johnson, Johnson, & Holubec, 1998; Kaldi, Filippatou, & Govaris, 2011; van Rooij, 2009; Veenman, Kenter, & Post 2000). However, no studies have investigated how PBL stimulated students' interest in STEM disciplines, which in turn, influenced their major selection. In addition, studies have analyzed neither which PBL factors affect students in terms of academic choice nor how PBL factors work in relation to each other. Therefore, the current study examines whether and how instructional strategies utilizing PBL approaches affect students in their intent to pursue a STEM major.

Intent to Pursue a STEM Major

Because of the interest among policymakers and educators in increasing the number of students pursuing STEM majors, factors contributing to STEM major selection and retention have been investigated. Studies (e.g., Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010; Maltese & Tai, 2011; Wang, 2013) on students' selection of and persistence in STEM majors have been based on SCCT (Lent, Brown, & Hackett, 1994; Lent et al., 2010), which was developed based on Bandura's (1986) general social cognitive theory. The SCCT proposes that students' self-efficacy and outcome expectations in studying mathematics and science are the primary predictors of their intent to pursue a STEM major. Maltese and Tai (2011) conducted regression analyses to assess the school-based factors relevant to students' persistence in completing STEM majors. Congruent with the SCCT, the results indicated that STEM-related enrollment and persistence were influenced by students' interest in and belief regarding the usefulness of STEM majors (Maltese & Tai, 2011). Wang (2013) examined how students' educational experiences at the secondary level played a critical role in fostering their interest and in developing predispositions toward STEM majors; in particular, Wang found that the exposure of students to mathematics and science courses was a stronger factor predicting the intention to pursue STEM majors than was mathematics achievement at the high school level. Byars-Winston et al. (2010) added ethnic factors and tested relationships among social cognitive, cultural, and contextual factors in relation to STEM degree selection and completion. The results indicated that ethnic variables were related to self-efficacy, which was mediated through interest in STEM and indirectly influenced students' selection of a STEM major.

These studies (i.e., Byars-Winston et al., 2010; Maltese & Tai, 2011; Wang, 2013) have indicated in common that students' interest in STEM fields is the critical factor in whether they major in STEM disciplines at the college level. In high school, students' own interests stimulate them to enroll in STEM courses; by increasing their exposure

to STEM disciplines, this influences their intent to major in a STEM field. Innate factors such as personal attribution and talent might affect their interest in choosing a specific major. However, external factors, including the learning environment, have also been indicated as important influences on students' interests (Akalin & Sucuoglu, 2015; Sengül & Dereli, 2013). It is thus critical to note that students' interest in STEM disciplines can be increased through altering the educational environment, such as by adopting educational activities or instructional strategies.

Students are also influenced in their intent to pursue STEM majors by outcome expectations and self-referenced beliefs pertaining to STEM. Students who believed STEM would be useful in the future have been found to be more likely to complete and earn STEM degrees (Lent et al., 1994; Maltese & Tai, 2011). Therefore, demonstrating the utility of STEM subjects is necessary for teachers to provide students with information regarding the significance and role of STEM fields in their future careers.

Whether demographic factors (e.g., ethnicity, gender, and socioeconomic status [SES]) influence students' choice of a STEM major has been debated. Maltese and Tai (2011) found that race/ethnicity was not a statistically significant indicator of the selection of a STEM major or persistence. On the other hand, a study conducted by Wang (2013) revealed that students of different ethnicities varied in their intent to pursue a STEM major. For example, ethnic minority students (i.e., African Americans, Latino/as, Southeast Asians, and Native Americans) are negatively affected by school and classroom climates including racial discrimination, which caused low self-confidence in pursing STEM majors (Cabrera, Colbeck, & Terenzini, 2001).

Compared with other factors, gender has been found to exert an especially pronounced effect in regard to the selection of a STEM major. In populations evenly split in terms of gender, it has been shown that fewer women than men select STEM majors (King, 2010; Prayor, Hurtado, DeAngelo, Blake, & Tran, 2009). As a result, women are underrepresented in the STEM workforce (National Science Board, 2008). Studies have indicated that formal and informal educational settings have led to a lack of female STEM majoring students and professionals (Prayor et al., 2009; Shapiro & Sax, 2011). The formal educational environment, encompassing curricula and academic interactions with teachers and peers, influences women's interests in STEM and, in turn, whether they select a STEM major (Kinzie, 2007; Shapiro & Sax, 2011). In addition, the informal educational setting increasing teachers and parents' gender-biased perception affected their female students/daughters in selecting their majors.

SES is also a critical factor influencing attitudes toward learning and academic achievement among students. As one environmental factor that affects students, economic status has often been measured based on the educational and income

levels of students' parents, students' involvement in loan programs, and students' eligibility for free or reduced-cost meals. The impact of students' SES on their intent to pursue a STEM major has varied among studies with different underlying contexts (Maltese & Tai, 2011; Wang, 2013). According to the results from Malteses and Tai's (2011) study, SES measured through parental education level and participation in loan programs and work-study was not statistically significant in predicting students' college persistence. Moreover, Wang (2013) found that students' college readiness in mathematics and science was associated with their STEM major selection, and this relationship was not significantly different across varied SES groups.

In contrast to other factors aforementioned, students' demographic characteristics cannot be altered through the adoption of an educational approach. However, teachers, educators, and policymakers may be able to facilitate the development of appropriate instructional strategies, enhance learning and teaching environments, and promote students' interest and motivation in and outcome expectations regarding STEM majors. Among the diverse educational approaches that have been taken to stimulate students' interest, belief in the benefits of, and intentions regarding STEM majors, the current study focused on PBL. In the following section, why the current study illuminates PBL and how PBL components enhance students' intent to pursue a STEM major are elucidated.

Project-Based Learning for STEM

PBL is an instructional approach providing "the contextualized, authentic experiences necessary for students to scaffold learning and build meaningfully powerful science, technology, engineering, and mathematics concepts" (Capraro, Capraro, & Morgan, 2013, p. 2). PBL has been discussed alongside and integrated into STEM education because it can bridge secondary STEM courses with post-secondary specializations and STEM professions (Capraro et al., 2013). In the real world, STEM professionals are expected to solve diverse, ill-defined, and non-routine problems that have multiple possible solutions. Similarly, PBL provides students with ill-defined and authentic tasks and encourages them to experience problematic situations in a school-based learning environment. Ultimately, PBL improves the quality of education and enables students to become ideal STEM professionals with 21st century skills after graduating from secondary and post-secondary institutions (Bell, 2010). For this reason, PBL has been introduced to teachers as an appropriate instructional approach and has been implemented into STEM classrooms.

The impact of PBL implementation in STEM classrooms has been investigated. The effects of PBL on students have been discussed within three domains: the affective, behavioral, and cognitive domains. Regarding the affective domain, students' interest, self-confidence, and self-efficacy have been examined. STEM classrooms integrating

PBL were found to exert a positive influence on students' interest in learning and their conviction in the utility of STEM subjects (Baran & Maskan, 2010). Furthermore, PBL activities increased student self-confidence and self-efficacy (Baran & Maskan, 2010). PBL is usually designed and implemented through collaborative group work; hence, PBL has also been found to exert a positive impact on students' communication and collaboration skills (Domínguez & Jaime, 2010; Kaldi et al., 2011; van Rooij, 2009). Finally, the positive effects of PBL on students in the affective and behavioral domains influenced their academic achievement (Han, Capraro, & Capraro, 2015). As students' interest in and positive attitudes toward learning STEM disciplines increased, their test scores and overall academic achievement improved.

Studies (i.e., Capraro et al., 2013; Han & Carpenter, 2014) have investigated the reasons behind the positive impact of PBL on students in the affective, behavioral, and cognitive domains. PBL exerts a positive influence because of its unique constructs and components of PBL. With Korean middle-school students as participants, Han and Carpenter (2014) validated five constructs of STEM PBL: self-regulated learning, collaborative learning environment, interdisciplinary learning environment, technology-based learning, and hands-on activities. Capraro et al. (2013) theoretically investigated components of PBL. It remains necessary to investigate how the constructs and components of PBL account for its effect on students' decisions regarding STEM majors. In this sense, the current study analyzed data pertaining to students' attitudes toward the constructs of PBL and examined the relationships among the constructs and the selection of a STEM major.

Case of Korea

The factors that influence Korean students selecting a post-secondary major have been investigated (Kim & Oh, 2013; Lee, 2014; Yeo & Lee, 2013). Gender was found to be a significant factor predicting students' collegiate major selection, especially among students selecting STEM fields (Kim & Oh, 2013). Men were more likely to select engineering fields than were women. Outside of STEM fields, gender was shown not to have a critical effect in determining college students' major selection (Yeo & Lee, 2013). Parental income and education level were shown to exert an impact on Korean students' selection of a major (Kim & Oh, 2013). Korean students whose parents were of higher educational backgrounds tended toward the humanities and social sciences rather than engineering. Finally, among Korean students, academic achievement in high school was a decisive predictor of college major selection. Korean students with higher levels of academic achievement in mathematics and science were more likely to select STEM majors, whereas those who were good at Korean and English were more inclined to choose majors in the humanities and social sciences (Kim & Oh, 2013; Song, 2014). Among Korean students, interest in STEM

courses has not been identified as a factor in predicting college major selection. However, based on existing literature (i.e., Song, 2014), it was surmised that Korean students' interest might be a factor in their decision to pursue a STEM major.

The current study focused specifically on PBL and its impact on students' intent to pursue a STEM major because PBL has been around for many years in Korea and has been examined as an effective instructional approach for the STEM disciplines. Classes integrating PBL in Korea have exerted a positive impact on students' self-directed learning skills, interest in subjects, and attitudes toward learning itself (Cho & Kim, 2010; Lee, 2014). Therefore, the present study sought to link the effect of PBL on students' interests to their intent to pursue a STEM major.

Theoretical Framework and Research Questions

The present study is based on Bandura's (1986) general social cognitive theory, the SCCT (Lent et al., 1944, 2000; Lent et al., 2010), and previous studies on students' selection of a STEM major (Byars-Winston et al., 2010; Lent, Lopez, Lopez, & Sheu, 2008; Maltese & Tai, 2011; Sahin, 2013; Shapiro & Sax, 2011; Wang, 2013; Zhe, Doverspike, Zhao, Lam, & Menzemer, 2010). The proposed model (see Figure 1) focused on the relationship between students' intent to pursue a STEM major and PBL as an instructional model that can influence students' interest in and outcome expectations regarding the selection of a STEM major (i.e., belief in the benefits of STEM fields). According to previous studies regarding the causal effects of PBL in STEM classes on students' interest and outcome expectations (i.e., Baran & Maskan, 2010; Domínguez & Jaime, 2010; Kaldi et al., 2011; van Rooij, 2009), students' attitudes toward instructional approaches for STEM were found to be linked with their belief in the benefits of pursuing STEM. The construct "belief in STEM benefits" was postulated as a mediator based on the SCCT literature and, in the model, was linked to students' intention to pursue a STEM major.
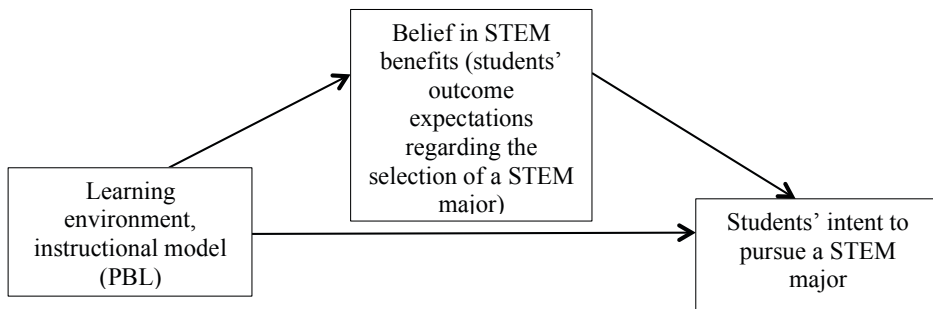

Figure 1. Hypothesized model.

Guided by the aforementioned studies and theoretical framework, the current study examined the direct and indirect impacts of students' attitudes toward STEM PBL on their interest in majoring in STEM disciplines. Specifically, this study addressed the following research questions:

Research Question 1: What are the relationships among the constructs concerning students' attitudes toward STEM PBL and their intent to pursue STEM majors in post-secondary education?

Research Question 2: Is there a mediator on the construct established in Question 1?

Research Question 3: How do the relationships described in Question 1 vary by gender?

Methods

Participants

The study participants were students enrolled at six secondary schools in Korea. The schools and students were selected by the availability sampling approach. Among the schools and teachers available to the author, six teachers at six schools consented to administer the survey in their classrooms; surveys were administered by the teachers rather than by the author. The schools were scattered throughout a large city in Korea and the areas in which the schools were located were, on average, in the middle for the city in terms of SES. A total of 840 students were surveyed; 24 students' responses were excluded because they did not answer the items or intentionally gave the same answers to all the items. Among the remaining participants ($n = 816$), 168 (20.6%) and 648 (79.4%) were middle school and high school students, respectively. Female and male students accounted for 60.7% ($n = 495$) and 39.3% ($n = 321$) of the sample, respectively.

Measures

The measurement instrument utilized was adopted from a previous study by Han and Carpenter (2014) and revised for the current study. The survey instrument was developed to investigate Korean students' attitudes toward STEM PBL and was verified in terms of reliability and validity. For reliability, Cronbach's Alpha was calculated. The validity of the instrument was established using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). The survey inquiring into students' perspectives on STEM PBL as a teaching-learning method initially consisted of 51 Likert-formatted items. Thirty-eight items were adopted from previous studies regarding self-regulated learning (Kim, 2011), collaborative learning (Lim, Cha, & Noh, 2001), beliefs in STEM benefits (Little & Hoel, 2011; Najafi, Ebrahimitabass, Dehghani, & Rezaei, 2012), technology-based learning (Najafi et al., 2012), and hands-on activities (Holstermann, Grube, & Bogeholz, 2010; Miller, 1990); 13 items

were created by the author. A five-point scale ranging from "strongly agree," "agree," "either agree or disagree," "disagree," and "strongly disagree" was used. Based on the EFA and CFA analysis results, 26 items and 5 constructs (collaborative learning (CO), technology-based learning (TE), self-regulated learning (SR), hands-on activities (HO) and belief in STEM benefits (BE)) were extracted and confirmed. There were five, five, six, five, and five items for CO, TE, SR, HO, and BE, respectively. These five factors pertaining to students' attitudes toward the STEM PBL teaching-learning method were assumed to be potential predictors of students' major selection. The values of reliability of each construct were acceptable for five constructs, having Cronbach's Alphas of .838 (CO), .846 (TE), .796 (SR), .876 (HO), and .887 (BE).

Two further questions were posed to students. One inquired as to their gender and the other asked whether they intended to pursue a STEM major in post-secondary school. The responses to these two items were coded dichotomously (female = 1, male = 0, and yes = 1, no = 0, respectively).

Data Analysis

Descriptive analysis. In the current study, composite variables were used in the structural equation modeling analyses. Based on the CFA results, composite variables were computed as mean values of the items involved in each construct (i.e., CO, TE, SR, HO, and BE). For the composite variables, descriptive statistics including means, standard deviations, skewness, and kurtosis were computed (Table 1). Means, standard deviations, and correlation coefficients were useful in constructing a proposed structure representing the relationships among the factors of the STEM PBL teaching-learning method and the outcome variable of major selection. For the dependent variable (i.e., STEM major selection), frequencies were reported because the variable was binary-coded.

Table 1
Descriptive Statistics

	Mean	SD	Skewness	Kurtosis
Collaborative Learning (CO)	3.676	0.733	-0.622	1.217
Technology-Based Learning (TE)	3.579	0.681	-0.305	0.442
Self-Regulated Learning (SR)	3.404	0.647	-0.330	0.759
Hands-On Activities (HO)	3.554	0.714	-0.218	0.127
Belief in STEM Benefits (BE)	3.785	0.655	-0.480	1.353
Frequency	STEM Major		Non-STEM Major	
STEM Major Selection	273		543	

Structural equation modeling. Based on the theoretical framework, constructs composing the measurement instrument were assumed and a CFA was performed for these constructs. Subsequently, SEM analyses were conducted to test the proposed conceptual model. The analyses were implemented using Mplus 7.0 (Muthén

& Muthén, 2010). For probit regression models, the weighted least square with adjustment in mean and variance estimator was used because the outcome variable was binary (Muthén & Muthén, 2010). Moreover, three fit indices (the chi-square and the degree of freedom [$\chi 2/df$], root mean square error of approximate [RMSEA], and comparative fit index [CFI]) were reported to analyze the overall model fit. The cutoff values for RMSEA and CFI for good fit were .07 and .95, respectively (Byrne, 1998; Hu & Bentler, 1999; Kline, 2005). The chi-square test was expected to be rejected in the event that the fit of the model was good.

Indirect effects. Among the five constructs of STEM PBL teaching-learning method, "hands-on activities" was hypothesized to serve as a mediator, converting the effects of students' attitudes toward STEM PBL into the intent to major in STEM disciplines. Therefore, direct and indirect paths from four constructs of the STEM PBL teaching-learning method to the outcome variable were estimated and tested for statistical significance.

Multiple-group analysis: Differences by gender. To answer the research question "How do the relationships described in Question 1 vary by gender?" multiple-group path analysis was employed (Kline, 2011). Three multiple-group path analyses were conducted. The first multiple-group path analysis was utilized to test whether there was an overall difference between male and female students. Next, a series of eight separate multiple-group path analyses were conducted to identify those paths in which male and female students differed significantly from one another. Finally, a third multiple-group path analysis, which incorporated the results of these eight separate analyses, was conducted. The first analysis only indicated the extent to which the assumed baseline model was aligned to each male and female student group, but the third analysis confirmed that there were statistically significant differences between male and female students on some specified paths.

Results

CFA Analysis Results

CFA was conducted in regard to the employed measurement instrument; the CFA results indicated that the measurement model fit the data well (RMSEA = 0.041, CFI = 0.981, $\chi 2/df$ = 189.243/80 [rejected]). The chi-squared test was rejected because it is extremely sensitive to sample size and the sample size of the current study was comparatively large (Brown, 2006; Marsh, Hau, Artelt, Baumert, & Peschar, 2006). All of the standardized factor loadings were above 0.680 and statistically significant ($p < .05$). The model fit indices and factor loadings indicated that the measurement model had good convergent validity (Kline, 2011). Based on the CFA results, the hypothesized measurement model, which was based on the correlation coefficients

of the variables and theoretical framework, was tested using SEM in order to answer the three research questions.

SEM Analysis Results

To test the hypothesized structural model, SEM analyses (e.g., path analyses) were conducted. A recursive path analysis model was developed in light of previous research results that disclosed the relationships among factors influencing students in their choice of a major. A composite variables model was used in the current study because using manifest variables was more likely to reflect the characteristics of the sample rather than of the population. Table 2 presents both covariance and correlation matrices that were used to determine whether the model fit the data.

The correlation coefficients of the relationships among the variables CO, TE, SR, HO, and BE were statistically significant. The relationships between STEM Major Selection and others were statistically significant with the exception of the relationships between STEM Major Selection and CO and between STEM Major Selection and SR. The hypothesized model was proven to fit the data (see Figure 2). All of the path coefficients were statistically significant with the exception of the path from SR to STEM major selection. Moreover, the model fit indices showed that the model had a good fit with the data ($\chi 2/df$ = 3.420/2 [not rejected], CFI = 0.994). Given that to be acceptable, CFI value must exceed 0.90, the current model was found to fit the data well (Byrne, 1998; Hu & Bentler, 1999; Kline, 2005).

Table 2
Correlation Matrices among Composite Variables

	1	2	3	4	5
1. CO	—				
2. TE	0.199**	—			
3. SR	0.360**	0.158**	—		
4. HO	0.337**	0.277**	0.322**	—	
5. BE	0.323**	0.265**	0.453**	0.379**	—
6. STEM Major Selection	-0.044	0.141**	0.007	0.194**	0.138**

Note. CO=collaborative learning; TE=technology-based learning; SR=self-regulated learning; HO=hands-on activities; BE=belief in STEM benefits; $**p < .01$; $*p < .05$.
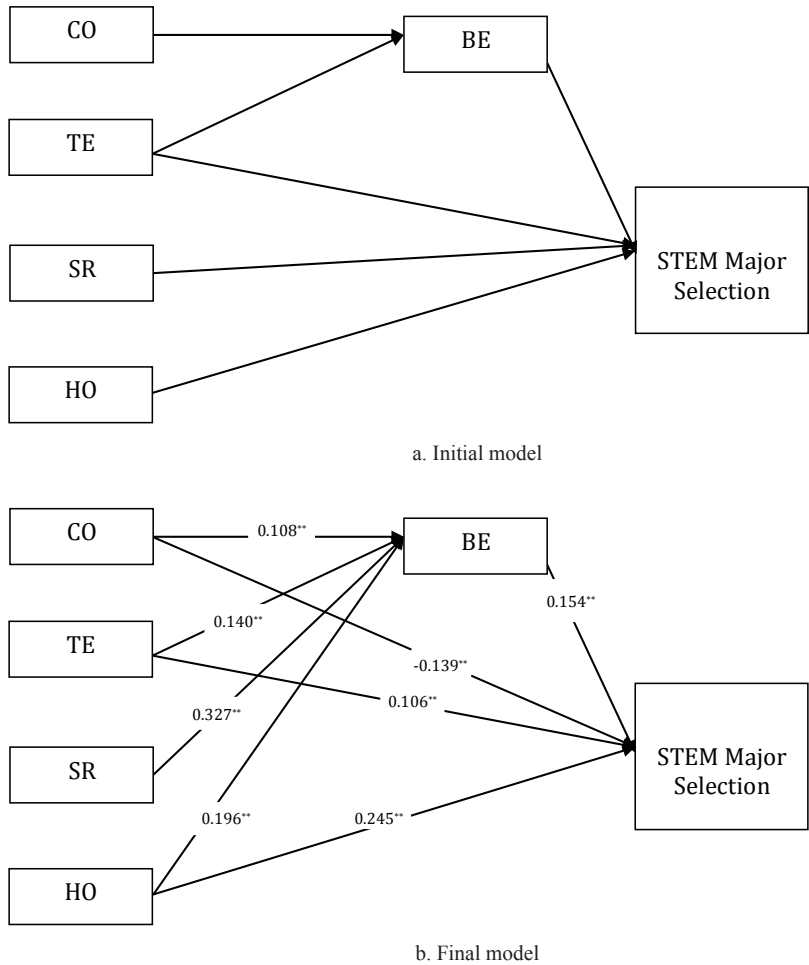
a. Initial model

b. Final model

Figure 2. Initial and final models. CO=collaborative learning, TE=technology-based learning, SR=self-regulated learning, HO=hands-on activities, BE=belief in STEM benefits.

The correlation matrix suggested that the constructs of CO and SR were unrelated with students' intent to select a STEM major. In an attempt at model trimming, structural models excluding either CO or SR were tested. Compared with the initial model, the model without SR had better model fit indices ($\chi2/df$ = 3.778/3 [not rejected], RMSEA = 0.018, CFI = 0.997). Because the latter model was nested within the initial model, the chi-squared value was utilized as an indicator of the goodness of the model fit and for evaluating whether it was a better model (Brown, 2006; Marsh et al., 2006). The latter model was consequently selected as the final model because the chi-square test was not rejected (p = .550). In sum, the results from the two SEM structural models supported the hypothesis that students' attitudes toward PBL components (i.e., CO, TE, SR, and HO) were related to their intent to pursue a STEM major indirectly through the belief in STEM benefits.

Mediation effects. In the models, the construct "belief in STEM benefits" played a role as a mediator between the four other constructs and the outcome variable (i.e., intent to pursue a STEM major). Mediation was tested using the delta method in Mplus 7.0 (MacKinnon, 2008; Muthén & Muthén, 2010; see Table 3). First, the direct effects (paths from the constructs, of collaborative learning, technology-based learning, and hands-on activities to the outcome variable) were statistically significant, with path loadings of -0.139, 0.106, and 0.245, respectively. The indirect effects of students' attitudes toward collaborative learning, technology-based learning, and hands-on activities on the intent to pursue a STEM major were also statistically significant, though the estimated values were much smaller than those of direct effects. In addition, the indirect effect from self-regulated learning to the selection of a STEM major was statistically significant with an estimated value of 0.050.

Table 3
Direct and Indirect Effects

Effects	Estimates
Effects from collaborative learning to the selection of a STEM major	
Indirect: STEM ← Belief in STEM benefits ← Collaborative learning	0.017**
Direct: STEM ← Collaborative	-0.139**
Effects from technology-based learning to the selection of a STEM major	
Indirect: STEM ← Belief in STEM benefits ← Technology-based learning	0.022**
Direct: STEM ← Technology-based learning	0.106**
Effects from self-regulated learning to the selection of a STEM major	
Indirect: STEM ← Belief in STEM benefits ← Self-regulated learning	0.050**
Effects from hands-on activities to the selection of a STEM major	
Indirect: STEM ← Belief in STEM benefits ← Hands-on activities	0.030**
Direct: STEM ← Hands-on activities	0.245**

Note. **$p < .05$.

Multiple-Group Analysis: Differences by Gender

Based on the final SEM model, in which no path was constrained to be equal across genders, the relationships among students' attitudes toward STEM PBL and major selection were investigated. The model fit indices for this first multiple-group path analysis indicated a good model fit ($\chi2 = 0.527$, $df = 2$; RMSEA < 0.001; CFI = 1.000). To examine the paths on which male and female students showed significant differences in terms of factor loadings, eight constrained path analyses were employed. In each path analysis, one path was constrained. The result of each constrained model was compared to that with all paths freed. The results of eight chi-square tests indicated that male and female students differed significantly from one another on the path leading from collaborative learning to belief in STEM benefits ($p < .05$) and the path from hands-on activities to belief in STEM benefits ($p < .05$) (see Table 4). The final multiple-group path model specifying these constrained paths was compared to the model with all six paths constrained. On the final multiple group path

model, the path from hands-on activities to belief in STEM benefits was statistically significant for both male ($\beta = .308$) and female ($\beta = .141$) students. In the case of the path from collaborative learning to belief in STEM benefits, the path coefficient for the male group was statistically significant ($\beta = .224$) whereas that for the female group was not.

Table 4

Chi-Square Difference Test Results for Multi-Group Path Analysis

Constrained Path	Chi-Square Value/*df*	*p*-value (Chi-Square Test for Constrained Path)
CO→BE	12.994/3	$p < .001^{**}$
TE→BE	0.693/3	$p = .684$
SR→BE	0.626/3	$p = .753$
HO→BE	14.885/3	$p < .001^{**}$
CO→STEM major selection	1.787/3	$p = .262$
TE→STEM major selection	2.394/3	$p = .172$
SR→STEM major selection	1.319/3	$p = .373$
HO→STEM major selection	1.071/3	$p = .461$

Note. CO=collaborative learning; TE=technology-based learning; SR=self-regulated learning; HO=hands-on activities; BE=belief in STEM benefits; $^{**}p < .01$; $^{*}p < .05$.

Discussion

The current study examined structural models to elicit the relationships among students' attitudes toward constructs of PBL and their intent to pursue a STEM major. According to the findings of the study, the components of PBL have direct and indirect effects on students' intent to choose a STEM major. In the sense that PBL is an appropriate and common pedagogical approach for STEM education in classrooms from kindergarten through the 12th grade, the present study has educational implications for research and practice regarding students' selection of a STEM major.

The results of this study imply that it is possible that specific instructional approaches influence students' intentions regarding major selection. In the study, students' attitudes toward PBL were linked with their intent to select a STEM major. The path coefficients from the PBL constructs (i.e., collaborative learning, technology-based learning, and hands-on activities) to the intent to pursue a STEM major indicated that students who felt positive about participating in PBL activities tended to belief more in STEM benefits and tended to select STEM majors at the college level. In other words, having classes integrated with PBL on offer might encourage more students to choose a STEM major.

Regarding the factors that influence students' intent to select or actual selection of a STEM major, researchers have investigated and focused on students' individual demographic characteristics, such as gender, ethnicity, and SES, as well as

environmental factors such as exposure to mathematics and science courses (King, 2010; Lent et al., 2010; Maltese & Tai, 2011; Prayor et al., 2009; Sahin, 2013; Shapiro & Sax, 2011; Wang, 2013). However, no studies have examined the impacts of instructional approaches on students' intent to pursue a STEM major. Specifically, it was necessary to scrutinize how PBL affects students' intent to select a STEM major because PBL has been illuminated as an effective instructional approach to maximize students' interest and academic achievement in STEM disciplines (Capraro et al., 2013). For this reason, the findings of the current study are significant in understanding the relationship between the instructional strategy implemented in STEM courses and students' intent to select a STEM major.

The present study provides additional evidence supporting why PBL needs to be implemented in secondary level courses. Many studies (Baran & Maskan, 2010; Dominguez & Jaime, 2010; Johnson et al., 1998; Kaldi et al., 2011; van Rooij, 2009; Veenman et al., 2000) have illuminated the positive impacts of PBL on students' attitudes and academic achievement and, accordingly, the necessity of implementing PBL for K–12 students. PBL activities elicit more positive attitudes among students regarding actual learning, improved communication and collaboration skills, and higher levels of academic achievement in STEM disciplines. The current study implicitly supported these findings of previous studies by connecting students' attitudes toward PBL to their intent to pursue a STEM major. The link between PBL and students' intent to select a STEM major might be explained through general social cognitive theory (Bandura, 1986) and the SCCT (Lent et al., 1994, 2000; Lent et al., 2010): PBL encourages students' interest in STEM majors, which in turn, stimulates their intent to major in STEM fields. In addition, this study provides a reason as to why exposure to mathematics and science courses increases the likelihood that students will select a STEM major (Wang, 2013): in other words, the current study explains *how* students should be exposed to mathematics and science courses. To encourage more students to select a STEM major, it is necessary not only to increase the duration students are exposed to mathematics and science but also to integrate mathematics and science courses with an appropriate approach utilizing PBL.

Additionally, this study provides other educational implications that might be applied to other instructional strategies including the components such as collaborative learning, technology-based learning, and hands-on activities. In the study, five PBL constructs were extracted and examined in terms of how they were related to the intent to pursue a STEM major. Certain components of PBL—collaborative learning, technology-based learning, and hands-on activities—had direct effects on students' intention to pursue a STEM major. In other words, any instructional approaches that include the components of collaborative learning, technology-based learning, and hands-on activities might exert similar impacts on students' intent to select a STEM major.

The model proposed and validated in this study indicated that beliefs in STEM benefits played a role as a mediator between other PBL components (i.e., collaborative learning, technology-based learning, self-regulated learning, and hands-on activities) and students' intent to pursue a STEM major. This finding is in line with those of Maltese and Tai (2011) and Byars-Winston et al. (2010) in the sense that students' outcome expectations regarding STEM fields play a critical role in their choice and pursuit of a STEM major. For the constructs of collaborative learning, technology-based learning, and hands-on activities, there were direct and indirect effects and the indirect effects partially explained the total effect. On the other hand, for the construct of self-regulated learning, the direct effect on students' intent to select a STEM major was not statistically significant and there was only an indirect effect. That is, the mediation effect of 'belief in STEM benefits' was complete between the variables, SR and STEM major selection. For the other relationships between independent variables except SR and STEM major selection, the mediation effects were partial. This might be because the construct, SR was less likely to include STEM components compared to the other constructs such as TE and HO.

The four indirect effects from each PBL construct to students' intent to major in a STEM field were all statistically significant. According to the previous studies, the relationships between STEM PBL components and students' beliefs in STEM fields (Baran & Maskan, 2010) and between students' beliefs in STEM fields and career choice (SCCT; Lent et al., 1944, 2000; Lent et al., 2010) have been disclosed. However, there were very limited studies linking these three constructs. For example, a previous study by Wang (2013) found that students' belief in the benefits of STEM had a direct effect on STEM major selection and did not find that relationship was mediated. The current study contributes to finding that the relationship between students' belief in the benefits of STEM and STEM major selection was statistically significant. This implies that promoting students' belief in the benefits of STEM fields is critical to increase the synergistic effect of PBL activities on students' positive attitudes toward majoring in STEM fields. To have more students choose STEM majors, it is important to provide not only the learning environment where students are encouraged in STEM PBL activities, but also opportunities to increase students' beliefs in STEM benefits in schools and mathematics classrooms.

Differences by gender were found in analyzing the model describing the relationships between students' attitudes toward PBL components and their intention to pursue a STEM major. Differences between female and male students were identified on the paths from collaborative learning to belief in STEM benefits and from hands-on activities to belief in STEM benefits. For male students, only the direct effects of these two PBL components were statistically significant, whereas for female students, the indirect effects were significant. This might explain why male

students are more likely to select a STEM major than are female students (King, 2010; Prayor et al., 2009). For example, it was found that male students with a positive attitude toward technology-based learning were more likely to select a STEM major, whereas female students were influenced indirectly by technology mediated by the belief in STEM benefits. In the case of the path from hands-on activities to belief in STEM benefit, the estimated path coefficient for male students was larger than that for female students. This might be explained by the fact that male students were more likely to have positive attitudes toward engineering components, including diverse hands-on activities (Felder, Felder, Mauney, Hamrin, & Dietz, 1995).

This study contributes to the understanding how PBL should be implemented in mathematics and science classrooms to encourage students to pursue STEM majors at the secondary level. The current study acknowledges that students' major selection might be affected by instructional approaches used in schools and not only by innate individual factors such as ethnicity, gender, and parental income and education. The use of instructional approaches encouraging students' interest in and belief in the benefits of majoring in STEM enhance the possibility that such students will desire to select STEM majors in college, contributing to the achievement of equity in educational opportunity.

Limitations of the Study

One limitation of the study is related to the use of students' self-reported measures: it could be contended that students who reported that they intended to pursue a STEM major could in fact have chosen a different major in the future. However, as Maltese and Tai (2011) stated, "the major students have in mind when learning high school is a strong predictor of their eventual degree field" (p. 899), students' intent to pursue a STEM major at the secondary level is a strong and significant predictor of their actual later major selection in STEM fields. In this sense, the reliability of the findings, based as they were on self-reported measures, might be guaranteed in the current research context. However, it is strongly suggested that future studies use self-reported measures and observed measures regarding the selection of a STEM to enable findings from both measures might be compared. In addition, the findings from the current study might not be generalizable to students in other countries because the participants in this study were all Korean students. Future studies could include students of different nationalities and following different curricula in order to determine how nationality may yield different results.

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