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Factors Influencing Student Satisfaction toward STEM Education: Exploratory Study Using Structural Equation Modeling

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Abstract: Learning satisfaction has a relationship with student outcomes. Furthermore, this has prompted many governments to increasingly implement STEM education-based learning. Many studies have examined the improvement of STEM education by teachers. However, the studies have not analyzed STEM education's effect on students' learning satisfaction. Extending the planned behavior theory, this study aimed to predict high school students' learning satisfaction with STEM education. The questionnaire developed from the TPB model was filled out by 174 high school students in Indonesia. Furthermore, AMOS and SPSS 23 software were used for structural equation model analysis. The results showed that seven of twelve hypotheses were supported. Subjective norm and playfulness factors of STEM education positively relate to students' attitudes toward STEM education. Attitude is the most important factor influencing student satisfaction and acceptance toward STEM education. Therefore, this study provides a theoretical and practical contribution to improving learning satisfaction in technology-based STEM education.

Keywords: STEM education; senior high school; TPB; learning satisfaction

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1. Introduction

The study of Science, Technology, Engineering, and Mathematics (STEM) education has increased in the last decade, showing its importance in improving students' abilities in the 21st century [1,2]. However, its implementation in Indonesia has many challenges. First, the teacher does not understand STEM education and how to implement it for students. Second, it combines interdisciplinary science, a challenge for schools and teachers accustomed to single-subject teaching. Other problems are class hours, communication on interdisciplinary science, teaching materials, and its relationship with Indonesia's standard curriculum [3].

Indonesia's learning curriculum is centralized, where the government monitors and evaluates teachers' school activities. The government has advised some schools in big cities to use STEM education-based learning. STEM education entered Indonesia in 2014, with Syiah Kuala University becoming one of the largest centers. In collaboration with SEAMEO and QITEP (https://www.qitepinscience.org/, accessed on 30 June 2022), the STEM education research center focuses on improving STEM education quality. They conduct various workshops and develop education-based learning to assist its implementation in schools. Examples of experiments include electroplating, aquaponics technology, electrical installation, and others related to technology and engineering from elementary to high school levels. Although STEM implementation has been running for more than five years, only a few studies measure its success [4–6]. The previous study primarily used cognitive learning performance to measure the quality of its implementation [7,8]. Additionally, several college studies have examined the effects of STEM education, though there is limited literature that focuses on K-12 students.

The success of implementing STEM education is measured in many ways. Previous studies used the perspective of student academic performance [9,10]. Other studies stated that academic performance is less effective in determining the success of implementing a new learning approach. Furthermore, several studies recommend analyzing student satisfaction as an alternative to successfully implementing a new learning model [11,12]. Student satisfaction reflects their perceptions of the learning experience with STEM education [13]. Student satisfaction is also an important outcome affecting motivation, ability, and the desire to participate in learning activities [14,15]. Furthermore, this study considered student satisfaction with STEM education as the dependent variable because it strongly relates to the perception of learning quality. Besides the importance of STEM education and its integration of various fields of science, unsatisfied students may be influenced by its difficulty to implement, impact, and inadequate facilities. Therefore, further studies should identify the predicted determinants related to student satisfaction with STEM education.

This study aimed to develop a new model to explore factors related to student satisfaction toward STEM education through attitude and acceptance. The following section elaborates on the theoretical background of predictors that may relate to student satisfaction with STEM education.

2. Literature Review

2.1. STEM Education in Indonesia

Common teaching and learning approaches used by teachers in Indonesia are problem-solving. Where learning activities are teacher-centered, students have less opportunities to participate. Furthermore, teachers rarely use technology-based learning media to explain the material. When STEM education was implemented in Indonesia, the shifting was established. Teachers with STEM education connect science, technology, engineering, and mathematics materials in instruction. The increase in the use of technology-based learning media influences pedagogical and technological knowledge.

STEM education was introduced in Indonesia by SEAQIS in 2015 through the 2015 IBSE-STEM Policy concerning cooperation agreements to organize training in STEM assisted by ATSE Australia. Cooperation between countries is encouraged to implement projects to strengthen the curriculum based on STEM education [9]. SEAQIS is one of the institutions appointed by UNESCO partners to make this program a success [16].

At the beginning of 2018, batch one STEM education training began to be pursued, containing teachers in West Java, Indonesia. In mid-2018, the achievements of technology-based experimental STEM products from batch one became the start and initial guideline for batch two training. This training is currently growing with the support and cooperation of PPPPTK IPA.

From August to October 2018, technology-based STEM experiments were implemented at various school levels. The experiments are mostly at the secondary school level, where students are more mature, careful, and knowledgeable than in elementary school. The experience of implementing teachers and product results are displayed in the STEM workshop. In 2019 and 2020, large-scale training was conducted to learn STEM-based education evenly distributed in Indonesia.

The Indonesian Ministry of Education monitors and supports collaborations and big plans to socialize STEM education [17]. It also hopes that the learning steps could be gradually combined with the national curriculum [9]. Therefore, teaching and learning activities in the future would be more scientific and fun, avoiding the lecture learning model mostly used by teachers [18,19].

Indonesia's STEM education training that produces pre-service and in-service teachers is technology- and project-based correlated with everyday life. Many studies have shown that project-based learning is student-centered and makes students more participative. This approach is suitable to be combined with STEM education, where learning is experiment-based. In line with this, several studies found that STEM education learning in the first week was filled with engineering design and theory cycles. It provided students with preparation for using STEM education experiments with technology, as well as discussing and formulating hypotheses about the product. The teacher provides brainstorming, experimental plans, and product goals before the scientific unit learning with engineering design begins.

Since 2014, several universities in Indonesia have been working to form lesson plans for experimental schools. Some studies conducted are the development of workbook-based STEM education, which improves students' abilities in every meeting, technology literacy, and outcomes. In contrast, this study focused more on the importance of student satisfaction in learning with STEM education than only technology literacy and outcomes.

After introducing the STEM education for more than five years and its implementation running in schools for approximately three years, it is necessary to understand students' acceptance, attitude, and satisfaction. Therefore, this study aimed to explore the factors related to students' attitudes and satisfaction toward STEM education. The results may help the Indonesian government develop STEM education-based learning. They could also provide deeper knowledge about important considerations when implementing learning in schools.

2.2. Theoretical Foundation and Hypotheses Development

This study proposed a comprehensive model to solve the problem and the need for further study on student satisfaction with STEM education. Figure 1 shows that the proposed model examines perceived usefulness, perceived convenience, facilitating conditions, subjective norm, playfulness, attitude, and collaborative learning. These predictors may affect student satisfaction with STEM education at the high school level. They are the combined results of previous studies derived from the theory of planned behavior (TPB) [20] and several theories about the acceptance model affecting student satisfaction [11,12,21]. The technology acceptance model theory was used because this study defined STEM education as a learning approach that integrates technology with other sciences. According to Zou [22] and Zobair [23], this theory could be used to analyze a person's intentions and acceptance of learning models related to new technology.

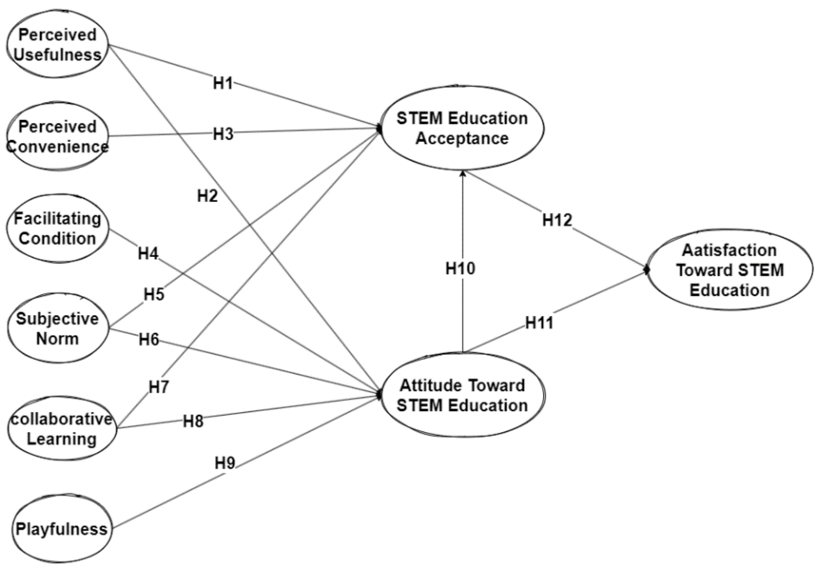

Figure 1. The proposed model with initial hypothesis.

2.3. Perceived Usefulness (PU)

PU with technology is how people believe that learning with technology-based STEM education helps them achieve learning goals. Previous studies found that PU positively and significantly relates to student attitudes and acceptance of the new learning approach [24,25]. Similarly, there is a positive relationship between PU and student satisfaction [26]. High school students may be highly satisfied with STEM education with technology-based learning when they believe technology helps them gain new knowledge.

2.4. Perceived Convenience

For students, determining convenient learning depends on time and effort [27]. Learning is convenient when it is fast, short, clear, and reduces the students' emotional and physical burden [28]. Joo [29] stated that convenience is similar to the TAM model's ease of use. It is felt by students when conducting STEM education to gain new knowledge.

From the self-determination theory perspective, perceived convenience is how people believe a model could help them achieve the desired goal [30]. Liao [31] found that perceived convenience affects one's motivation and intention to use technology-based learning models. Additionally, Yoon and Kim [31] extended TAM by adding a perceived convenience variable to analyze the acceptance of new technology.

2.5. Facilitating Conditions

Facilitating conditions (FC) are facilities and environmental factors affecting the perception of doing a task [32]. FC facilitates support, including technical assistance, teacher knowledge, and knowledge about STEM education. It could influence students' attitudes toward technology-based STEM education learning. According to Wijaya [33], technical support was the highest factor influencing teachers to implement new technology. Other studies also found FC related to the intention to use technology-based learning models [34–36]. Teo [37] stated that FC affects user satisfaction, and Ngai et al. [38] found that it affects attitudes toward computer use. Therefore, the FC factor may influence student satisfaction toward STEM education.

2.6. Subjective Norm

Subjective norm is the acceptance of social pressure to perform a behavior [39]. It is also a perception that important people support or do not support one's behavior [40]. In this study, the subjective norm is where people around students believe technology-based STEM education is important learning. Previous studies found that these norms affect technology acceptance and student attitudes [37,41]. Therefore, subjective norms relate to student attitudes and acceptance toward technology-based STEM education.

2.7. Playfulness

Perceived playfulness may also influence students' attitudes toward STEM education. Studies on technology show that user playfulness is the strongest determinant associated with using new technology-based learning approaches [42,43].

Perceived playfulness is the mindset with three dimensions, including how individuals feel their attention is focused on STEM education with technology experiments, curiosity when conducting experiments, and learning is fun and interesting. Students have a pleasant experience when conducting the experiments in groups. Experiment-based learning is sometimes liked by students and provides intrinsic motivation. Extrinsic motivation is the desire to do something because it is fun, clear, and valuable [44]. In contrast, intrinsic motivation is the desire to be seen in an activity driven by passion [45].

Perceived playfulness when using learning or objects is related to technology in previous studies. Davis [46] found that playfulness positively influences a person's attitude toward new systems and learning. Therefore, the higher the perceived playfulness students feel in learning technology-based STEM education, the better their attitude [47].

2.8. Attitude toward STEM Education

Attitude is the desire to do or use something and positive or negative feelings toward an action or system [48]. This study defined attitude toward STEM education as the level at which students have negative or positive feelings toward technology-based STEM education lessons. Previous studies found that attitude toward using embodies successful implementation [24,49,50]. Attitudes toward conformity affect behavior intention, technology acceptance, and perceived learning [51,52]. Therefore, this study hypothesized that attitude affects student satisfaction with technology-based STEM education.

2.9. Collaborative Learning

Compared to traditional classroom settings, collaborative learning in STEM education transforms the learning environment with ICT-assisted experimentation. It enables students to encourage collaboration and build higher knowledge [53]. Collaborative learning embeds the integrated power of many sciences into learning through large-scale networked education [54,55]. It also encourages students to work together to solve life problems [56,57]. In this case, the teacher is only a tutor helping students overcome difficulties conducting experiments and group discussions. Therefore, collaborative learning may relate to student acceptance of technology-based STEM education.

2.10. STEM Education Acceptance

STEM education acceptance is the willingness to learn using STEM education. Many people have used and developed acceptance, such as Venkatesh [58] and the TAM model [59], to understand the technology acceptance phenomenon. This study synthesized the technology acceptance theory in the UTAUT model [32] into technology-based STEM education. Many studies have modified the UTAUT model in psychology, information systems, marketing and banking, and education [22,60–62]. In the UTAUT model [32], technology acceptance is influenced by performance expectancy, perceived convenience, subjective norms, and facilitating conditions adopted in this study. Therefore, this study hypothesized that STEM education acceptance is influenced by PU, PC, SN, and collaborative learning, and it affects student satisfaction with technology-based STEM education.

2.11. Satisfaction toward STEM Education

Student satisfaction is the emotions after having a learning experience with technology-based STEM education. This implies the importance of helping students' post-adoption behavior [63,64]. Student satisfaction is an important factor affecting learning interest and outcomes [65,66]. It is widely used to measure the success or failure of a learning model or approach, especially in education, where student satisfaction is prioritized [67]. Student satisfaction toward technology-based STEM education strongly relates to their learning outcomes. Therefore, various studies examine the factors affecting student satisfaction [14,68,69].

This study used the perceived dimensions of internal factors and educational dimensions as variables to predict the factors related to student satisfaction with STEM education. It used six independent variables, two intermediate variables, and one dependent variable connected into twelve initial hypotheses shown in Figure 1 and Table 1.

Table 1. Initial hypotheses about the factors related to student satisfaction toward technology-based STEM education.

Hypothesis	Hypothesis Description
H1	Perceived usefulness has a relationship with STEM education acceptance.
H2	Perceived usefulness has a relationship with student attitude toward technology-based STEM education.
H3	Perceived convenience has a relationship with STEM education acceptance.
H4	Facilitating conditions have a relationship with student attitude toward technology-based STEM education.
H5	Subjective norm has a relationship with STEM education acceptance.
H6	Subjective norm has a relationship with student attitude toward technology-based STEM education.
H7	Collaborative learning has a relationship with STEM education acceptance.
H8	Collaborative learning has a relationship with student attitude toward technology-based STEM education.
H9	Perceived playfulness has a relationship with student attitude toward technology-based STEM education.
H10	Student attitude toward STEM education with technology has a relationship with STEM education acceptance.
H11	Student attitude toward STEM education with technology has a relationship with student satisfaction toward technology-based STEM education.
H12	STEM education acceptance has a relationship with student satisfaction.

2.12. Participants

This study aimed to build a model to determine the factors related to student satisfaction toward STEM education at the high school level. Based on the theoretical foundation, eight determinants were examined for their relationship with student satisfaction. All students were informed that this online questionnaire was only used for study data, and their identity would be protected. The questionnaire was distributed at the STEM education experimental school guided by the SK university. Furthermore, this study used purposive sampling and the google questionnaire platform for the online questionnaire distribution. Therefore, the identity of the questionnaire filler was ascertained anonymously.

A total of 174 valid responses were collected from May to June 2022. The respondents comprised 118 female and 56 male students participating in teaching and learning activities with STEM education at least once. Furthermore, most teachers were divided into groups of more than three for STEM education. Complete data are shown in Table 2.

Table 2. Basic student information.

Data Demographic		N	Percentage
gender	female	118	67.8%
	male	56	32.2%
class	10	70	40.2%
	11	83	47.7%
	12	21	12.1%
Ever carried out a STEM education	1 x	104	59.7%
	2–3 x	30	17.2%
	More than 3 x	40	22.9%
The number of group members when conducting the STEM education experiment	2 students	47	27.0%
	3 students	35	20.1%
	More than 3 students	92	52.9%

2.13. Instrument

This study used online google questionnaires (see Appendix A) and conducted a voluntary and anonymous survey. The first part of the questionnaire indicated students' basic information, experiences with STEM education and the predictors related to satisfaction with STEM education. It used a five-point Likert scale ranging from one (strongly disagree) to five (strongly agree) [70]. The scale indicated the student's level of agreement with the statement on the questionnaire. The original questionnaire had nine latent variables, including perceived usefulness (three items), perceived ease of use (three items), and facilitating condition (three items). Other latent variables were playfulness (three items), subjective norm (three items), attitude toward STEM education (three items), behavior intention toward STEM education (three items), collaborative learning (four items), and student satisfaction toward STEM education (three items), resulting in twenty-eight items.

The questionnaires were sent to three experts on STEM education studies to check the appropriateness and clarity of all items and constructs. They were corrected, discarding two items (play two and SN1) because they were unclear and inappropriate in the construct.

2.14. Data Analysis

An initial analysis was conducted using AMOS and SPSS software to show whether the data could answer the study objectives. Structural equation modeling (SEM) was also applied because it allows simultaneous analysis of many variables needed and tests the relationship with factor analysis [71]. Confirmatory factor analysis (CFA) testing was first performed to confirm the variables' validity and reliability, which estimated the instrument's internal consistency before processing data using SEM [72]. The Cronbach alpha value must exceed 0.6 to meet the convergent validity criteria [73]. Second, the factor loadings of observed items must exceed 0.5 [74]. Furthermore, the overall fit model in SEM is usually assessed based on the goodness-of-fit indices (GFI) value exceeding 0.90. The parsimonious goodness-of-fit index (PGFI) must exceed 0.50 [73]. RMR must be smaller than 0.08, including the minimum Chi-square value (CMIN) and the ratio of Chi-square to degrees of freedom (where 2/df must be less than 5.0) [75]. The hypothetical model is supported when all the value requirements for SEM are met.

3. Results

This section presents the proposed SEM model's verification to determine the factors related to student satisfaction with STEM education. First, it displays descriptive statistical data and normality tests, followed by the reliability and validity tests. The last section presents the results of SEM and initial hypothesis testing.

3.1. Descriptive Statistics and Normality Test

Table 3 shows descriptive statistics of all observed items in this study. Based on the definition from Kline [76], the data normality is measured based on the skewness and kurtosis, which must be at the limit of ± 3. In this study, the highest and lowest kurtosis values were 2.985 and 0.198, respectively, while the skewness ranged between -1.229 and -0.280. Therefore, the skewness and kurtosis values met the normal distribution criteria and were useful parameters in SEM.

Table 3. Descriptive statistics and normality test.

Variable	Mean	Standard Deviation	Excess Kurtosis	Skewness
PU1	4.221	0.791	2.437	−1.167
PU2	4.129	0.752	2.136	−1.090
PU3	4.202	0.800	2.113	−1.109
PEU1	3.638	0.813	1.435	−0.351
PEU2	3.798	0.800	1.832	−0.487
PEU3	4.031	0.779	2.902	−0.841
SN1	3.699	0.800	2.145	−0.491
SN2	3.681	0.757	2.214	−0.333
SN3	3.896	0.788	2.153	−0.571
FC1	3.902	0.867	1.204	−0.607
FC2	4.239	0.797	2.362	−1.192
FC3	3.712	0.804	1.582	−0.356
PLAY1	3.908	0.790	2.322	−0.664
PLAY2	3.466	0.824	1.395	−0.390
PLAY3	3.902	0.785	2.405	−0.669
CL1	4.012	0.775	2.345	−0.978
CL2	4.006	0.787	2.985	−1.154
CL3	4.037	0.782	2.326	−1.229
CL4	3.724	0.809	1.463	−0.296
ATT1	3.957	0.786	2.425	−0.689
ATT2	3.748	0.762	2.218	−0.377
ATT3	3.859	0.798	2.231	−0.690
ACC1	3.951	0.820	2.282	−0.852
ACC2	3.914	0.839	2.293	−0.841
ACC3	3.761	0.835	1.288	−0.417
SAT1	3.870	0.763	0.198	−0.280
SAT2	3.773	0.754	2.489	−0.463
SAT3	3.865	0.795	1.903	−0.491

3.2. Reliability Analysis

Data reliability was seen from the Cronbach alpha value to measure each construct's internal consistency. Table 4 shows that the Cronbach alpha value is between 0.705 and 0.889. According to Hair et al. [73], the Cronbach alpha value must be greater than 0.70. Therefore, the questionnaire items have high reliability and internal consistency between variables. The next step checked the loading factor, composite reliability (CR), and AVE value to analyze convergent validity. The loading factor, CR, and AVE must be higher than 0.5, 0.7, or 0.5 [74]. In this study, the lowest factor loading, CR, and AVE values were 0.75, 0.90, and 0.76, respectively. Therefore, the proposed model has good convergent validity.

Table 4. Measurement construct validity with the factor loading, CR, and AVE.

Construct	Items	Factor Loading	CR	AVE	Cronbach Alpha
PU	PU1	0.86	0.94	0.84	0.875
	PU2	0.91			
	PU3	0.88			
PEU	PEU1	0.86	0.93	0.81	0.853
	PEU2	0.81			
	PEU3	0.80			
SN	SN1	0.79	0.94	0.88	0.705
	SN2	0.83			
FC	FC1	0.75	0.94	0.84	0.764
	FC2	0.79			
	FC3	0.87			
PLAY	PLAY1	0.93			
			0.92	0.85	0.886
	PLAY3	0.90			
CL	CL1	0.87			
	CL2	0.94	0.94	0.83	0.853
	CL3	0.90			
ATT	ATT1	0.89	0.95	0.87	0.857
	ATT2	0.91			
	ATT3	0.90			
ACC	ACC1	0.97			
	ACC2	0.95	0.93	0.81	0.889
	ACC3	0.87			
SAT	SAT1	0.91			
	SAT2	0.83	0.90	0.76	0.887
	SAT3	0.87			

3.3. Validity Analysis

Hair [73] suggested checking convergent and discriminant validity. Convergent validity is seen in the average variance extracted (AVE) value. Table 5 shows that all AVE values exceed 0.5, indicating that all constructs are acceptable and useful for further analysis.

Table 5. Discriminant validity result and root of average variance extracted.

	PU	CL	PLAY	FC	SN	PEU	ATT	ACC	SAT
PU	**0.310**								
CL	0.235	**0.346**							
PLAY	0.275	0.313	**0.374**						
FC	0.242	0.258	0.295	**0.320**					
SN	0.222	0.259	0.269	0.249	**0.304**				
PEU	0.264	0.257	0.314	0.272	0.288	**0.344**			

Table 5. *Cont.*

	PU	CL	PLAY	FC	SN	PEU	ATT	ACC	SAT
ATT	0.276	0.269	0.338	0.278	0.278	0.315	**0.383**		
ACC	0.298	0.311	0.358	0.288	0.276	0.296	0.372	**0.442**	
SAT	0.259	0.250	0.318	0.262	0.265	0.302	0.352	0.355	**0.373**

The discriminant validity was analyzed by assessing the square root of AVE for all variables. Table 5 shows that the AVE value is greater than the inter-construct correlations, implying that discriminant validity is accepted [77].

3.4. Model Fit Assessment

The initial model tested was concluded to identify and interpret the results of the fit index from the model estimation. There are many ways to interpret the fit model tested by looking at CMIN/df, RMSEA, GFI, and AGFI [78]. The model is also tested by evaluating TLI, NFI, and CFI, as well as parsimonious fit with PNFI and PGFI reference indicators [61]. This study used the three methods to test model fit (Table 6).

The data processing results using AMOS software showed that the Chi-square value is 429,521 with 248 degrees of freedom. This indicates that the CMIN/df value is 1.75 in the limit between $1 < x < 3$. Furthermore, many studies suggest checking the goodness-of-fit index by considering the variance and covariance predicted in the reproduced matrix [65,79]. A higher GFI value of 0.80 is acceptable because it indicates a better model fit. In this study, the GFI value reached 0.88. Unlike the Chi-square, the RMSEA reference indicator considers the estimated parameters but not the sample size. Therefore, an RMSEA value less than 0.08 indicates an accepted model [80], and an RMSEA value smaller than 0.05 indicates a perfect model. This study's RMSEA value is 0.06, implying an acceptable model. For incremental fit measurement, the values of NFI, CFI, and AGFI must be greater than 0.8 to achieve an acceptable fit model [81]. In this study, the values of NFI, CFI, and AGFI exceeded 0.8. Some of the literature uses parsimonious fit measurement to determine model fit. A parsimonious model is the simplest and sharpest model to explain the analyzed phenomenon [82]. In this study, the entire parsimonious fit index exceeded 0.05, signifying the model is suitable. These three fit model tests confirm that the proposed structural model in Figure 2 is acceptable and appropriate for analyzing and interpreting the factors related to student satisfaction toward STEM education.

Table 6. Absolute, incremental, and parsimonious fit measurement.

Measurement	Indicator	*p*-Value	Recommended Criteria
Absolute fit	CMIN/df	1.75	1 < x < 3
	GFI	0.88	>0.8
	RMSEA	0.06	<0.08
	RMR	0.05	<0.08
	NFI	0.85	>0.8
Incremental fit	CFI	0.80	>0.8
	AGFI	0.82	>0.8
Parsimonious fit	PNFI	0.29	>0.05
	PGFI	0.60	>0.05

The linear correlation coefficient (R2) [83] is the most important value for determining whether the proposed structural model strongly explains the factors influencing student satisfaction toward STEM education. Cohen [84] stated that an R2 value greater than 0.26

(26%) was strong enough to explain a model. In this study, the R-value for acceptance toward STEM education was 78.4%, student attitude toward STEM education was 73.0%, and student satisfaction toward STEM education was 70.4%. Therefore, the proposed model explains the factors related to student satisfaction with STEM education.

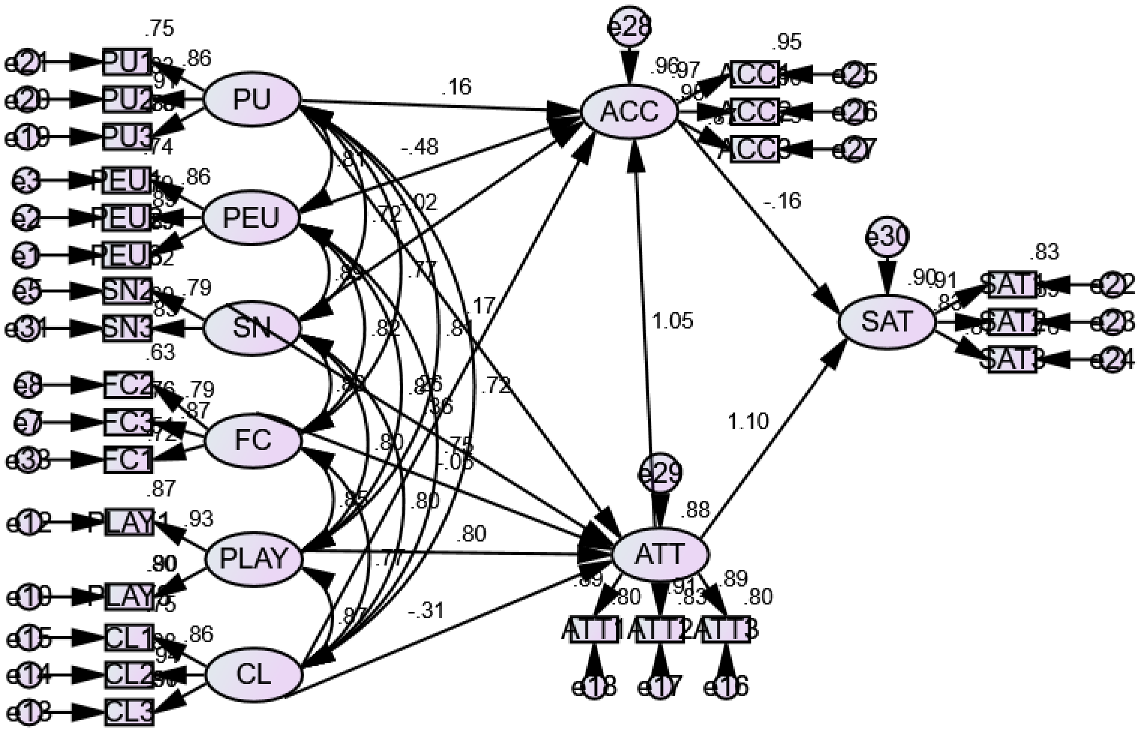

Figure 2. Whole set observation of the measurement model.

3.5. Structural Model and Hypothesis Testing

This study examined the statistical significance of the 12 initial hypotheses about the relationship with student satisfaction with STEM education. It determined the standardized regression coefficients between the dependent and independent variables. Furthermore, the study analyzed the significance of the *p*-value on each coefficient derived from the SEM output. The accepted hypothesis is where a statistically significant relationship in the predicted direction is confirmed. Table 7 and Figure 3 show three hypotheses with a significant level reaching 0.01 and at a significant level of 0.05 and 0.10 against seven hypotheses.

Table 7. Coefficient and hypothesis testing. ***: $p < 0.001$.

Hypothesis	Parameter			Path Coefficient (β)	SE	CR	*p*-Value	Interpretation		
								0.1	0.05	0.01
H1	PU	→	ACC	0.190	0.137	1.385	0.166	Rejected	Rejected	Rejected
H2	PU	→	ATT	0.184	0.130	1.417	0.156	Rejected	Rejected	Rejected
H3	PEU	→	ACC	−0.539	0.239	−2.262	0.024	Accepted	Accepted	Rejected
H4	FC	→	ATT	−0.054	0.154	−0.352	0.725	Rejected	Rejected	Rejected
H5	SN	→	ACC	−0.022	0.227	−0.096	0.923	Rejected	Rejected	Rejected
H6	SN	→	ATT	0.398	0.188	2.119	0.034	Accepted	Accepted	Rejected
H7	CL	→	ACC	0.295	0.140	2.109	0.035	Accepted	Accepted	Rejected
H8	CL	→	ATT	−0.324	0.153	−2.117	0.034	Accepted	Accepted	Rejected

Table 7. *Cont.*

Hypothesis	Parameter			Path Coefficient (β)	SE	CR	*p*-Value	Interpretation		
H9	PLAY	→	ATT	0.796	0.199	3.992	***	Accepted	Accepted	Accepted
H10	ATT	→	ACC	1.149	0.178	6.437	***	Accepted	Accepted	Accepted
H11	ATT	→	SAT	1.101	0.252	4.361	***	Accepted	Accepted	Accepted
H12	ACC	→	SAT	−0.150	0.198	−0.759	0.448	Rejected	Rejected	Rejected

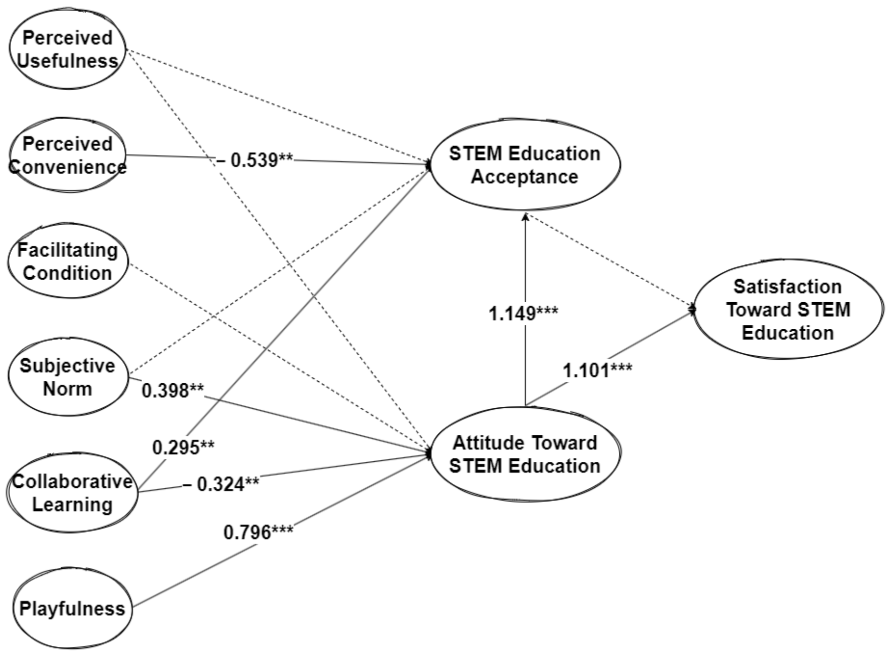

Figure 3. Final model with a coefficient (β) and *p*-value; a dotted line means an insignificant relationship. **: $p < 0.01$; ***: $p < 0.001$.

The findings showed that PU did not significantly correlate with STEM education acceptance or student attitude ($p > 0.05$), hence H1 and H2 were rejected. PEU had a relationship with STEM education acceptance (β = −0.539, $p < 0.05$), supporting H3 (PEU → ACC). Furthermore, FC had no significant relationship with attitude toward STEM education ($p > 0.05$), denoting H4 was rejected. SN does not significantly affect STEM education acceptance ($p > 0.05$), thereby H5 was rejected. In contrast, SN significantly correlates with attitude toward STEM education (β = 0.398, $p < 0.05$), supporting H6. Collaborative learning on STEM education has a relationship with STEM education acceptance (β = 0.295, $p < 0.05$) and attitude toward STEM (β = −0.324, $p < 0.05$), supporting H7 and H8. Moreover, the playfulness variable had the strongest relationship with students' attitudes toward STEM (β = 0.796, $p < 0.01$), supporting H9. The attitude had significant relationships with STEM education acceptance and student satisfaction toward STEM education (β = 1.149, $p < 0.01$) and (β = 1.101, $p < 0.01$), also supporting H10 and H11. Based on the coefficient, students' attitude strongly correlates with STEM education acceptance and satisfaction. Additionally, STEM education acceptance has no significant relationship with student satisfaction toward STEM education, meaning H12 was rejected.

4. Discussion

This study focused on integrating high school STEM education by predicting factors related to student satisfaction. It proposed a model based on the theory of planned behavior (TPB) added with predictors from the literature review.

Students might assume that when they feel the STEM education with technology experiment is relatively easy, their acceptance decreases, as shown by the PEU coefficient of acceptance of −0.184. High school students think experimental STEM education with technology should integrate several science fields with certain difficulties. When the STEM education experiment is too easy, high school students may feel they cannot improve their abilities. They are not challenged to experiment with technology-based STEM education. Moreover, students feel they are more accepting of learning commonly used by teachers. This finding supports previous studies which showed that easy activities did not improve student outcomes [85,86]. However, further understanding using qualitative studies is needed to explain these findings.

Subjective norms affect students' attitudes toward STEM education. The success of implementing learning aids is inseparable from the help of the people around the users [41,87]. Similarly, the success of technology-based STEM education depends on the role of the government, schools, and teachers. Students assume that their attitude cannot be separated from the support of the people that think it provides many opportunities to develop 21st century skills and knowledge to apply in life daily. The stronger the subjective norm, the better the student's attitude toward technology-based STEM education.

Collaborative learning in STEM education encourages students to communicate and increase their satisfaction in teaching and learning activities [88]. It allows them to talk, discuss, and convey their ideas in groups. Furthermore, collaborative learning relates to the acceptance of technology-based STEM education. Students assume that learning has a relationship with their acceptance of technology-based education. This education is a series of experiments difficult to conduct individually. Furthermore, students think that success in conducting experiments on technology-based STEM education requires collaboration. This implies they think collaborative learning is related to their acceptance of technology-based STEM education. However, students believe collaborative learning reduces their attitude toward STEM education. This is because learning in Indonesia mostly used a scientific approach or individual- and teacher-centered methods before STEM education. Therefore, students are not accustomed to working in groups and prefer individual- to experiment-based learning that requires cohesiveness. In some cases, groups with more members increase the possibility of conflicts of ideas, making the students emotional. This aspect provides input for teachers to guide and monitor experiments and student discussions. The teacher must mediate and provide a way out with deliberation when there are differences in opinions within the group during technology-based STEM education experiments.

Perceived playfulness is an advantage of technology-based STEM education. The findings showed that perceived playfulness has the strongest relationship with student attitudes. It has the largest positive indirect effect on student satisfaction toward technology-based STEM education. The model allows students to experiment inside and outside the classroom, making the learning process flexible. Unconsciously, students learn to solve complex problems related to everyday life as a team. The joy of experimenting increases their attitude toward technology-based STEM education, supporting previous studies [89,90].

Students' attitudes toward technology-based STEM education are the strongest determinants compared to acceptance and satisfaction. This implies the importance of improving the effectiveness of STEM education implementation in Indonesia. When students' attitudes improve, they easily accept STEM education-based learning. Similarly, they are more satisfied with experimental STEM education-based learning with technology. This supports a previous study finding that attitude toward a learning model or new technology significantly affected the intention to use the technology [91,92].

Students' acceptance of technology-based STEM education indirectly significantly increased their satisfaction. High school students feel that their satisfaction is more influenced by their attitude. However, further studies should examine other predictors affecting student satisfaction with technology-based STEM education.

Facilitating conditions did not significantly correlate with high school students' attitudes toward technology-based STEM education-based learning. These include teachers ready to help students overcome difficulties experimenting and schools that provide the needed facilities. The schools in question are equipped with complete laboratories to conduct STEM experiments. Furthermore, high school students feel confident and able to conduct their STEM experiments, indicating that their attitude is not influenced.

5. Theoretical and Practical Implications

This study provided theoretical and practical implications for increasing student satisfaction with technology-based STEM education. First, it is to develop a model to explain the factors related to student satisfaction with technology-based STEM education. The proposed model provides empirical evidence of student satisfaction. Second, this study provides new knowledge about the theory of student satisfaction in STEM education. The information from this new model's development contributes to STEM education's future development. This is useful for school governments and teachers to identify the factors to be considered when implementing STEM education in schools.

Practically, this study showed the relevance of student attitude and satisfaction by analyzing the factors significantly affecting the two variables. Student attitude could be improved by increasing the effectiveness of STEM education learning. This study found that subjective norms significantly affect student attitude toward STEM education. Therefore, educational institutions and teachers should create a conducive environment and spearhead the use of STEM education-based learning. The finding of playfulness implies that schools and teachers should integrate fun and exciting activities that generate pedagogically satisfying interest among students when learning with STEM education. It is also important to incorporate new innovations in experiments conducted by students. Although STEM education is rarely applied to learning activities in Indonesia, the existing experiments may always be interesting for students.

Learning using STEM education has challenges and problems. However, this approach is accepted by students because they are happy with learning activities that require teamwork. In today's era, knowledge should be balanced with the ability to work in a team. The important collaborative skills should be possessed in the 21st century. Therefore, this finding is expected to spur teachers to continue using STEM education-based learning. It could also promote students to collaborate when experimenting in STEM education than traditional or individualized teacher-centered learning.

Student attitude significantly affects their acceptance and satisfaction with STEM education. They feel that they recognize the benefits of STEM education on their learning outcomes. Furthermore, this study is beneficial to the government and academics that focus on developing STEM education in Indonesia. It could help them understand various important factors concerning student acceptance and satisfaction with STEM education. The findings provide a basis for evaluating student attitude, acceptance, and satisfaction with STEM education. Additionally, they contribute to the development of a model to analyze student acceptance.

6. Conclusions

This study tested the proposed model developed from the modified TPB model with literature review predictors to understand the determinants related to student satisfaction toward technology-based STEM education in Indonesia. Increasing student satisfaction may increase the effect of STEM education learning on student outcomes. Therefore, this study provides a better understanding of the factors to be considered to increase student satisfaction toward STEM education for governments, institutions, and teachers. Although STEM education is sustainable, it does not automatically increase student acceptance and satisfaction. The most important thing is to improve students' attitudes through support from schools and teachers. This could help students become more familiar with technology-based STEM education. The success of increasing student satisfaction is influenced by internal and external factors.

7. Limitations and Future Directions

Although this study achieves the research objectives and provides several valuable implications, this study has several limitations. First, the study was limited to the school experiment at the senior high school level in collaboration with the Syiah Kuala University in Indonesia. Therefore, the findings should be generalized with caution. Future studies should use larger samples from various countries. Second, this study also used TPB as the base model, while student satisfaction toward STEM education could still be analyzed in many models. Additionally, it was a quantitative study, implying the need for qualitative and longitudinal studies in the future.

The results showed how attitude and collaborative learning in STEM education affect student satisfaction. However, future studies could consider constructs such as student academic achievement, intention to use, and actual use of STEM education. The findings could provide additional knowledge on marginal processes and situations that describe STEM education's effect on student satisfaction.

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Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Questionnaire items.

Construct	Items	Items (Indonesian Version)	References
Perceived useful	STEM learning helps me to gain more knowledge through experiments.	Pembelajaran STEM membantu saya untuk mendapatkan lebih banyak ilmu melalui experiment	[59,93]
	Learning by doing in STEM lessons is very useful for me.	Learning by doing pada pelajaran STEM sangat bermanfaat bagi saya	
	I feel STEM learning is very useful for my future.	Saya merasakan pembelajaran STEM sangat berguna bagi masa depan saya	
Perceived easy to use	I do not find it difficult to learn with STEM-based learning.	Saya tidak merasa kesulitan belajar dengan pembelajaran berbasis STEM	[59,94]
	I can follow directions and experiments easily.	Saya dapat mengikuti arahan dan melakukan experiment dengan mudah	
	I easily obtain much useful knowledge from STEM activities.	Saya dengan mudah mendapatkan banyak ilmu yang bermanfaat dari kegiatan STEM	

Table A1. *Cont.*

Construct	Items	Items (Indonesian Version)	References
Subjective norm	My teacher uses STEM-based learning when teaching.	Guru saya menggunakan pembelajaran berbasis STEM saat mengajar	[40]
	The government has a program to encourage STEM-based learning.	Pemerintah mempunyai program untuk mendorong pembelajaran berbasis STEM	
	The school has a STEM-based learning program.	Sekolah mempunyai program pembelajaran berbasis STEM	
Facilitating conditions	I do not need to provide tools for experimentation, and the school already provides them.	Saya tidak perlu menyediakan alat untuk berexperiment, sekolah sudah menyediakannya	[58,95]
	The teacher is ready to help me if I have trouble doing experiments.	Guru siap membantu saya jika saya kesulitan untuk melakukan experiment	
	My team and I have enough knowledge to experiment.	Saya dan tim mempunyai pengetahuan yang cukup untuk melakukan experiment	
Perceived playfulness	I feel happy learning at school using STEM-based learning.	Saya merasa senang belajar di sekolah dengan menggunakan pembelajaran berbasis STEM	[96]
	I spend my free time at home continuing unfinished experiments at school.	Saya menghabiskan waktu luang saya di rumah untuk melanjutkan experiment yang belum selesai di sekolah	
Collaborative learning	I feel STEM learning effectively gets students to work together while conducting experiments.	saya merasa pembelajaran STEM efektif untuk membuat para siswa bekerjasama saat melakukan experiment	[43,97]
	I feel STEM learning is effective for making students discuss conducting experiments.	saya merasa pembelajaran STEM efektif untuk membuat para siswa berdiskusi untuk melakukan experiment	
	STEM learning improves my knowledge and skills through group discussions.	Pembelajaran STEM meningkatkan pengetahuan dan kemampuan saya melalui diskusi kelompok	
	Collaboration in STEM learning is better than traditional learning.	Kerjasama pada pembelajaran STEM lebih baik dibanding pembelajaran tradisional	
attitude	I like it when teachers use STEM learning.	Saya senang jika guru menggunakan pembelajaran STEM	[92,98]
	I prefer learning that uses STEM learning.	Saya lebih menyukai pembelajaran yang menggunakan pembelajaran STEM	
	I think using STEM learning is a good idea.	Saya pikir menggunakan pembelajaran STEM adalah ide yang baik	
STEM education acceptance	I am happy to accept STEM-based learning.	Saya senang untuk menerima pembelajaran berbasis STEM	[99,100]
	I will be happy if the teacher can continue to use the STEM approach next semester.	Saya akan senang jika guru dapat terus menggunakan pendekatan STEM pada semester depan	
	I will advise teachers; therefore, we will learn with a STEM approach.	Saya akan memberikan saran kepada guru agar kita dapat belajar dengan pendekatan STEM	
Learning satisfaction	I am very satisfied with learning with STEM learning.	Saya sangat puas belajar dengan pembelajaran STEM	[21,63]
	My team is very satisfied with the experiments in STEM learning.	Tim saya sangat puas dengan experiment pada pembelajaran STEM	
	The teacher directs each team to learn to experiment well.	Guru mengarahkan setiap tim untuk belajar melakukan experiment dengan baik	
	I am very satisfied if the teacher uses STEM learning in the classroom.	Saya sangat puas jika guru menggunakan pembelajaran STEM di kelas.	

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