Future Primary Teachers' Beliefs, Understandings and Intentions to Teach STEM

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Abstract

The development of integrated skills and knowledge in science, technology, engineering, and mathematics (STEM) are necessary in order to deal with challenging complex situations and should be developed from primary school. It is expected that early experiences can influence and foster a deep and ongoing interest in STEM. In order to provide these early experiences in their future classrooms, preservice teachers need subject matter knowledge, pedagogical content knowledge and expertise to innovate and deal with STEM in their own future classrooms This research focused on the beliefs and understandings preservice primary teachers (n=119) have about teaching and to what extent they are prepared to teach STEM subjects in primary schools. A questionnaire based on the position paper on STEM issued by the Australian Office of the Chief Scientist (Prinsley & Johnston, 2015) and guided by the theory of reasoned action was used as the basis of this study. The data was analysed qualitatively and quantitatively. The results suggest the preservice teachers in this study believed there should be STEM in the curriculum, but they were not confident in their ability to teach STEM without more professional preparation and development.

Keywords: STEM education; preservice teacher education; primary school; STEM.

Introduction

There is a shift in education to prepare students from primary level on, to deal with challenging complex situations through creative solutions, effective communication and problem solving abilities. Skills in science, technology, engineering, and mathematics (STEM) must be developed from primary schools (National Research Council [NRC], 2015) because early interest and types of experiences can influence and foster interest in STEM. Falk, Dierking, Staus, Wyld, Bailey, & Punnel (2016) pointed out important principles for improving STEM learning and generating interest among primary and secondary school children. Major aspects of these principles include involving everyday experiences, involving practitioners and learners in the research process, using emerging technology to continue to shape content and practices, and considering broader sociocultural and political contexts.

Future teachers play a vital role in implementing STEM in classrooms with creative and innovative practices. Recently the idea of an educational infrastructure has been reframed by STEM educators using the concept of an ecosystem of social networks, peers, educators, friends and families incorporating in school and out of school contexts of learning (NRC, 2015). All these are relevant to existing and future practices for STEM teaching and learning in classrooms. Integrated approaches to teaching and learning and teacher preparation are key to producing a generation who is interested and skilled in STEM. It is important to attract high achievers and boost the rigour of STEM within both primary school teaching and pre-service teacher preparation (Prinsley & Johnston, 2015). Preservice teachers need subject matter knowledge, pedagogical content knowledge (PCK) and expertise to innovate and deal with STEM in their own future classrooms (Abell, 2007 & 2008). Preservice teacher education provides an opportunity to develop PCK and to use creative and innovative practices. It is through professional learning that knowledge and competency through incorporating STEM are developed (Berry, Loughran, & VanDriel, 2008; Lee, Brown, Luft, & Roehrig, 2007).

At present there is a deficit of integrated STEM frameworks internationally (Zeidler, 2016). Accordingly, there is an urgent need to educate preservice teachers about science related challenges (Tobin, 2016). Because STEM has significance in everyday practices (Civil, 2016), future STEM education and research must be positioned within life-wide, life-deep and life-long approaches (Rahm, 2016). Future teacher preparation and the capacity to deal with STEM are necessary for changing classrooms with an integrated STEM approach.

Future Primary Teachers' Beliefs, Understandings and Intentions

Future teachers particularly at the primary level require confidence, competence and skills in integrating STEM into their daily classroom practices. STEM education policies need to be implemented that have clear purposes and understandings around developing instructional material and 21st century teaching practices. Beliefs regarding STEM influence attitudes associated with science and technology. Beliefs also influence how people interact as a part of the natural environment (Schultz, 2001). The interpretation of scientific and technological issues associated with STEM not only requires background science knowledge but also positively held beliefs about STEM (Thomm & Bromme, 2011).

Interdisciplinary approaches (Johnson & Adams, 2011) to democratic civic informed decision making aligns with the Next Generation Science Standards (Next Generation Science Standards [NGSS] Lead States, 2013) and National Research Councils (NRC, 2013) focus on integrating divergent thinking and leads to democratic civic practices for informed decision making scenarios in classrooms. Such approaches involve different ways of thinking, solving problems and communicating. Students learn to use a range of technologies to plan, analyze, evaluate and present their work. They learn valuable reasoning and thinking skills that are essential for functioning both within and outside the school environment using creativity, design principles and processes (Victorian Curriculum Assessment Authority, 2017). Technology such as the Internet requires students to take the initiative in designing active learning that emphasizes the interaction rather than just the content (Anderson, 2004).

It is important that future primary teachers have the competency and confidence to teach STEM education that is connected to the daily lives of their learners. Perkins (2014) uses the concept of 'life-worthy learning' to discuss an approach to educating young people for a changing world. This involves teaching students to deal responsibly with issues associated with change. Education should address understanding as well as societal implications of democratic informed decisions and actions (Schreiner, Henriksen & Hansen, 2005). Levinson, Kent, Pratt, Kapadia, & Yogui, (2012) argue that if students are provided with authentic scenarios in which decision making involves considerations of different viewpoints, they will be more responsible and look for evidence in democratic decision making. In reality students should be capable of using their knowledge, not just in a scientific context but also for societal and environmental needs (Fernandez-Mazanal, Rodriguez-Barreiro, & Carrasqer, 2007).

Issues in STEM education are very complex and solutions require political, economic, cultural, social and individual decisions and actions. School science programs that allow participation in society provide potential for lifelong participation in learning of STEM related societal issues. In this process teachers and students are required to extend their knowledge of science procedures and make connections to democratic civic decision making (Fensham, 2015 & 2016). The knowledge gained from practical life oriented and life related situations, and connected to daily life may provide students with better confidence and competence to function effectively as informed citizens (Ryder, 2001). An ideal education program targeting STEM issues encourages students to actively participate in societal issues investigating democratic civic decision-making by selecting suitable contexts that are related to the daily lives of students (Liu, Lin & Tsai, 2010; Dede, 2009 & 2013). This provides a basis for uninterrupted lifelong learning related to what is important in day to day life and the ability to cope with changes in their daily lives (Roth & Lee, 2004).

Methodology

Background

This study focused on gaining evidence about the beliefs, understandings and intentions of future primary teachers in STEM education. These beliefs, understandings and intentions are interlinked in terms of background knowledge and teacher capacity to integrate STEM in their future teaching practices. Positive beliefs and understandings can provide confidence, competence and skills to deal with STEM and to design and teach STEM programs in schools. This study looked into details of how the belief system positioned and lead to preservice teachers' understandings. The aspects of beliefs, understandings and intentions that were investigated are included in Figure 1.

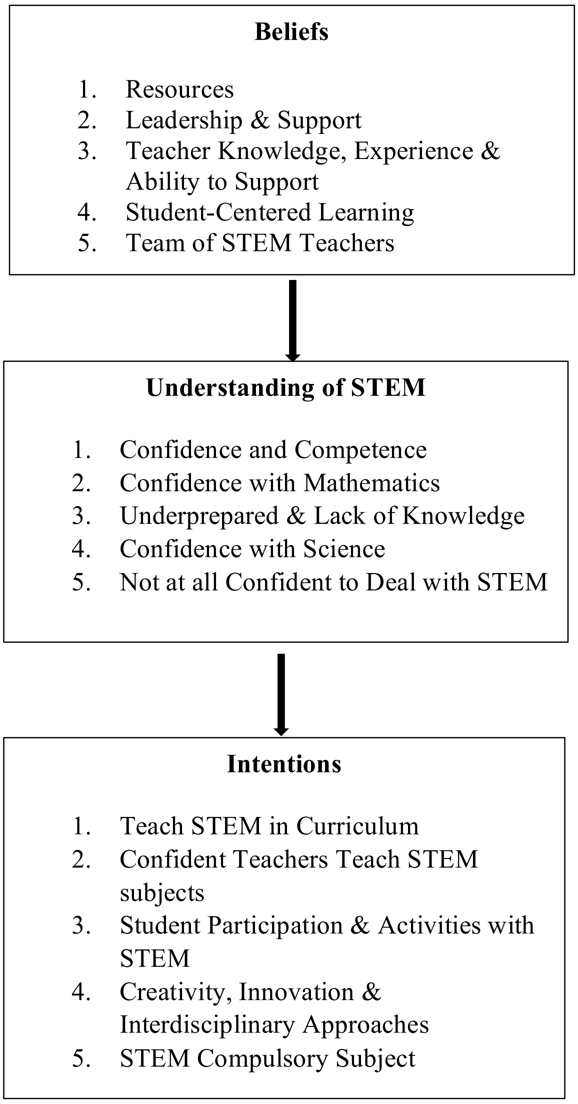

Figure 1: Aspects of beliefs, understandings and intentions of future primary teachers regarding STEM.

Purpose and Research Questions

The purpose of this research was to investigate future primary school teachers' beliefs, understandings, and intentions regarding STEM, their confidence to teach, and their intention toward STEM. This is viewed from the perspective of their background and capacity to deal with STEM in their teaching career. The research questions guiding this study were:

1. What beliefs and understandings do preservice primary teachers have about teaching STEM subjects in primary schools?
2. To what extend are preservice primary teachers prepared and intend to teach STEM subjects in primary schools?

Methods

Instruments

In this study, the research instruments were designed to elicit the responses of preservice teachers based on a questionnaire using the theory of reasoned action (Ajzen & Fishbein, 1980). The design of the instruments drew upon previous questionnaires using the theory of reasoned action (Kurup, Hackling & Garnett, 2005), as well as aspects identified for transforming STEM teaching in Australian primary schools (Prinsley & Johnston, 2015). The instrument contained a total of fifteen items and five items each for beliefs, understandings and intentions toward STEM on a five point Likert scale (1 strongly disagree to 5 strongly agree). There were also descriptive questions to investigate teachers' capacity to teach STEM in each of beliefs, understandings and intentions sections. The descriptive answers to the questionnaire were read and reread to code patterns and categories emerged from these codes. Reliability and validity are discussed in the relevant analysis and results sections.

Descriptive statistics, Cronbach's alpha, and composite reliability were conducted. The bootstrapping procedure was used to analyze validity through the average variance extracted (AVE). Partial Least Squares (PLS) estimation does not directly provide significance tests. Significance levels for loadings, weights, and paths were also calculated through bootstrapping. Two thousand bootstrap samples were used to empirically calculate standard errors and evaluate statistical significance.

Participants

This study surveyed 119 preservice teachers from an Australian University. The sample included 26 males (21.8%); 83 females (69.7%) and 10 not wishing to disclose their gender (8.4%). These preservice teachers had primary science, mathematics, and design and technology methods courses in their degree program.

Instruments

To examine the relationship among beliefs, understandings and intentions, Partial Least Squares (PLS) estimation-based Structural Equation Model (SEM) was used. Structural Equation Model is a largely confirmatory, rather than exploratory, technique to determine whether a certain model is valid. This model is not only used to assess the structural model (path relationships among latent variables) but also evaluates the measurement model (loadings of observed items on their latent variables). PLS is a well-established technique for estimating path coefficients in SEM accomplished using Ordinary Least Squares (OLS) techniques that have minimal demands on measurement scales, sample size, and residual distributions (Chinn & Newsted, 1999). Hence, it is more suitable for research with small to medium samples, non-normal distributions. The PLS method has gained interest and use among researchers (Chin, 1988; Compeau & Higgins, 1995).

Results

The aspects of beliefs, understandings, and intentions mentioned in Figure 1 were examined and responses were initially analyzed to look at the frequency of agreement and disagreement. Table 1 and 2 provided details of latent factors and their indicators in terms of beliefs, understandings and intentions toward STEM in their future career. A frequency of items was analyzed. The responses indicate that all aspects were considered to be high in agreement (agree and strongly agreement) based on their frequency.

Table 1: Latent factors and their indicators.

Latent factors		**Indicators**
Belief	B1	STEM education begins in primary school
	B2	We cannot be innovative and creative unless we have a quality education system
	B3	STEM education can produce skills needed in the future
	B4	We need high quality teachers at all levels
	B5	Primary schools need specialist science, technology and mathematics teachers
Understanding	U1	Attracting high achievers in STEM to primary school teaching
	U2	Boosting the science, technology and mathematics
	U3	Should have a specialist STEM teacher
	U4	Should be a national professional development
	U5	Primary school principals should be leaders in STEM
Intention	IT1	Teaching STEM will make teaching and learning more interesting and connected to daily life
	IT2	Mathematics is central and students' success in STEM depends upon understandings and ability to apply mathematics.
	IT3	Every primary teacher should be supported with specialist STEM teacher to build effective STEM education
	IT4	There should be a separate subject in university teacher education program fully focused on STEM
	IT5	Teachers ability, skills and interest in STEM will transform creativity and innovation among children

Table 2: Frequency of questionnaire items.

Item	Strongly disagree	Disagree	Not Sure	Agree	Strongly Agree
Belief					
B1	2 (1.7%)	2 (1.7%)	20 (16.8%)	51 (42.9%)	44 (37.0%)
B2	4 (3.4%)	11 (9.2%)	10 (8.4%)	49 (41.2%)	45 (37.8%)
B3	0	0	8 (6.7%)	47 (39.5%)	64 (53.8%)
B4	0	0	4 (3.4%)	28 (23.5%)	87 (73.1%)
B5	0	10 (8.4%)	30 (25.2%)	49 (41.2%)	30 (25.2%)
Understanding					
U1	0	3 (2.5%)	27 (22.7%)	77 (64.7%)	12 (10.1%)
U2	0	4 (3.4%)	14 (11.8%)	76 (63.9%)	25 (21.0%)
U3	1 (0.8%)	11 (9.2%)	29 (24.4%)	56 (47.1%)	22 (18.5%)
U4	2 (1.7%)	3 (2.5%)	19 (16.0%)	49 (41.2%)	46 (38.7%)
U5	1 (0.8%)	12 (10.1%)	52 (43.7%)	35 (29.4%)	19 (16.0%)
Intention					
IT1	0	6 (5.0%)	13 (10.9%)	65 (54.6%)	35 (29.4%)
IT2	0	9 (7.6%)	34 (28.6%)	53 (44.5%)	23 (19.3%)
IT3	1 (0.8%)	8 (6.7%)	30 (25.2%)	60 (50.4%)	20 (16.8%)
IT4	4 (3.4%)	5 (4.2%)	31 (26.1%)	50 (42.0%)	28 (23.5%)
IT5	1 (0.8%)	4 (3.4%)	15 (12.6%)	66 (55.5%)	32 (26.9%)

We ran a factor analysis with principal axis factoring. In order to determine whether the factor analysis was appropriate for our data set, we checked the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO statistic of 0.728 was above 0.500, suggesting that the data was suitable for factor analysis. Moreover, Bartlett's test resulted in a highly significant chi-square statistic (Chi-Square = 406, p-value < 0.001), indicating adequate correlation among the items.

Preliminary reliability of Cronbach's coefficient was 0.440, 0.551 and 0.622 for belief, understanding, and intention respectively. The Cronbach's alpha coefficient increased to 0.443 or 0.509 if questions B1 or B2 were omitted from Belief. Then the Structural Equation Model (SEM) was used to identify the relationship between beliefs, understandings and intentions to deal with STEM during their future career.

Figures 2 and 3 provided initial SEM model and modified SEM model of the beliefs, understandings and intentions by these preservice teachers towards STEM education. The difference between these two models was B1, B2 or neither. We carried out bootstrapping to check the significance of each indicator (2000 samples, 100 Cases). Based on Figure 2, we found both loadings of B1 and B2 were not significant with t-statistics were 1.04 and 1.43 respectively at 5% level of significance which were consistent with the preliminary reliability result. So the model in Figure 3 was used in this study and the results are explained below.

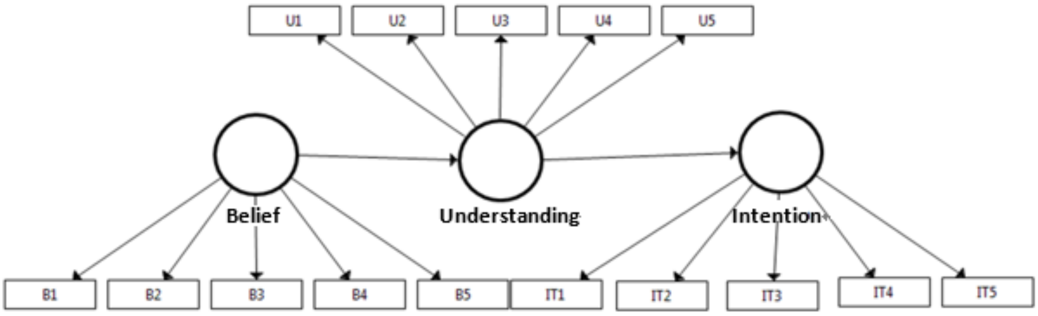

Figure 2: Initial Structural Equation Model of STEM.

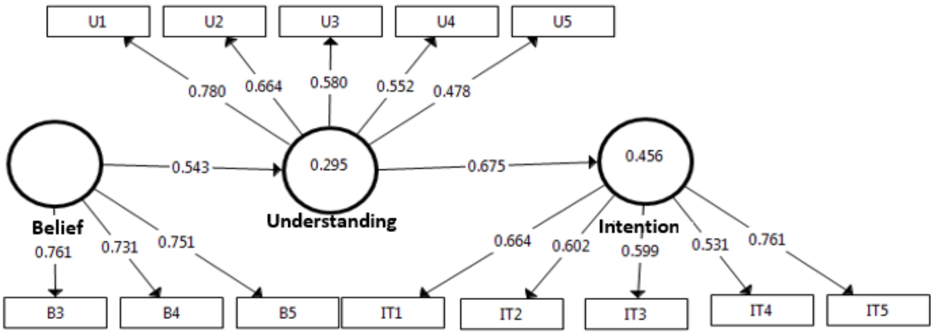

Figure 3: Modified Structural Equation Model of STEM.

Measurement Model (Outer Model)

Reflective constructs in PLS analysis need to be evaluated with respect to their internal consistency reliability, indicator reliability, convergent validity, and discriminant validity (Hair et al. 2011).

Internal Consistency Reliability

The reliability of the reflective measurement model (Figure 3) can be tested by "Cronbach´s alpha" and "composite reliability." Traditionally, "Cronbach's alpha" is used to measure internal consistency reliability but it tends to provide a conservative measurement in PLS-SEM. Prior literature has suggested the use of "Composite Reliability" as a replacement (Bagozzi and Yi, 1988; Hair et al., 2012). Composite reliability (construct reliability) analyses the strength of all indicators' correlations with their construct. Composite reliability (CR) should be 0.7 or higher. If it is an exploratory research, 0.6 or higher is acceptable (Bagozzi and Yi, 1988). Table 3 presented the results summary from the modified model, which showed the CR for all three latent variables were all above 0.7 and Cronbach´s alpha in belief and intention are all above 0.6, understand is very close to 0.6. The internal consistency reliability in this study was established according to the CR value.

Indicator Reliability

As the reliability of indicators varies, the reliability of each indicator should be assessed. Indicator reliability is the proportion of indicator variance that is explained by the latent variable, which is showed in Table 3. Usually 0.7 or higher is preferred. If it is an exploratory research, 0.4 or higher is acceptable (Hulland, 1999). U3, U4, U5 and IT2-4 are all below 0.4 as showed in table 3, and literature suggest to eliminate indicators only rigorously if their loadings are lower than 0.4 (Hair et al. 20ll). Additionally bootstrapping was carried out to check the significance of each indicator (2000 samples, 100 Cases). As indicated in Table 3, all indicators were significant on at least a 5% level of significance (two-tailed t-test), so even though the indicator reliability was not fully established, we couldn't delete any item for they were all significant.

Convergent Validity

Construct validity, determined through the presence of convergent and discriminant validity, demonstrates how well the measurement items relate to the constructs. Convergent validity is the extent to which the scale correlates positively with other measurements of the same construct. An established rule of thumb is that a latent variable should explain a substantial part of each indicator's variance, usually at least 50% (Bagozzi and Yi, 1988). To check convergent validity, each latent variable's Average Variance Extracted (AVE) is evaluated which represents the amount of variance a construct captures via its items relative to the amount of variation due to measurement error. Again from table 3, we found that only "Beliefs" AVE value is greater than the acceptable threshold of 0.5, but not the other two. Convergent validity is not well established. This indicated that measurement items relating to the "Understanding" and "Intention" might not well be established.

Discriminant Validity

Discriminant validity analyzes whether the construct has more variance with the own indicators than with others. Fornell and Larcker (1981) suggest that the square root of AVE in each latent variable can be used to establish discriminant validity, if this value is larger than other correlation values among the latent variables. To do this, square root of AVE is manually calculated for "Belief" (0.748), "Understanding" (0.620) and "Intention" (0.636). The latent variable "Beliefs' square root of AVE is 0.748. This number is larger than the correlation values between the latent variables understanding and intention, which is 0.543 and 0.411 respectively. The "Belief" and "Understanding" scales measure theoretically different constructs, "Belief" and "Intention" scales measure theoretically different constructs as well. However, Understandings square root of AVE is 0.620, which is smaller than the correlation between "Intentions" 0.675, so discriminant validity was not fulfilled. The "Understanding" and "Intention" scales measure theoretically not the different constructs.

Structural Model (Inner Model)

We next examined the overall explanatory power of the structural model, the amount of variance explained by the independent variables, and the magnitude and strength of its paths, where each of our hypotheses corresponds to a specific structural model path. The R^2 which is used to measure the model's explanatory power, was 0.295 for understand, indicating that 29.5% of the total variance in understand was explained by "Belief". 45.6% of the total variance in intention was explained by "Belief". The explained variation should exceed 10% to qualify for suitable explanatory power. All of the path coefficients were statistically significant ($p<0.001$) based on bootstrapping, "Belief" to "Understand" is 0.543 ($t=7.648$, $p<0.001$), "Understand" to "Intention" is 0.543 ($t=10.637$, $p<0.001$). The total effect of understand to intention is 0.675 ($t=10.638$), "Belief" to "Intention" is 0.367 (indirect effect, $t=10.638$), "Belief" to "Understand" is 0.543 ($t=7.648$).

Table 3: Results summary of the modified model.

Variable	Mean	SD	loading	Indicator Reliability	Composite Reliability	AVE	Cronbach's Alpha	R square	T-Statistics
Belief					0.792	0.559	0.610		
B3	4.470	0.622	0.761	0.579					9.704
B4	4.700	0.53	0.731	0.534					9.122
B5	3.830	0.905	0.751	0.564					10.652
Understanding					0.752	0.384	0.584	0.295	
U1	3.820	0.633	0.780	0.608					12.456
U2	4.030	0.682	0.664	0.441					8.362
U3	3.730	0.899	0.580	0.336					5.788
U4	4.130	0.888	0.552	0.305					4.941
U5	3.500	0.91	0.478	0.229					4.580
Intention					0.770	0.404	0.628	0.456	
IT1	4.080	0.777	0.664	0.440					9.287
IT2	3.760	0.853	0.602	0.362					7.114
IT3	3.760	0.843	0.599	0.358					6.550
IT4	3.760	1.025	0.531	0.282					4.627
IT5	4.020	0.863	0.761	0.579					12.388

Discussion

Only minimal aspects of STEM are presently being taught with in primary schools and this is considered insufficient to produce future citizens capable of dealing with the challenging demands for sustainable living in the 21st century. There is no integrated teaching and learning framework available internationally to deal with STEM (Zeidler, 2106), however, governments internationally have accepted the need to incorporate STEM education for primary schools (Prinsley & Johnston, 2015). Issues in STEM education needs solutions from various angles, but a good starting point would be in pre-service courses at higher education institutes. Primary school teachers need to extend their knowledge of science and technology procedures and link this knowledge to their informed decision making regarding issues of sustainable living for the future (Fensham, 2015 & 2016). The results of this study indicate there is a relationship of beliefs, to understandings, and to intentions regarding STEM, rather than any direct relationships of beliefs to intentions or understandings to intentions among future primary teachers participated in this study.

Based on this study future teachers expressed their preparedness and concerns for taking up STEM in their future teaching. They have university and practicum experience and the reflections are based on their limited experience with STEM education. Participants reported that, there is not much happening at present in their school practicum experience and in their university courses regarding preparations for teaching STEM education and this is explicitly mentioned in their responses. This limits the capacity of these future teachers’ to deal with STEM in their own upcoming future classroom practices. However, the following aspects were mentioned by future teachers in this study, which are very important for them in dealing with STEM in their classroom practices:

- Resources and leadership for making things happening in a school environment,
- Teacher knowledge of science, mathematics and technology to demonstrate to students the issues associated with real world,
- Collaboration with teams of teachers using an integrated approach.

The concerns expressed by the future teachers in this study based on their university and practicum experiences include a lack of confidence:

- To teach mathematics and science,
- In terms of understandings associated with the teaching of STEM and ability to incorporate in the curriculum,
- To teach using a creative, innovative and interdisciplinary approaches and student participation in learning activities.

It is suggested that STEM should be a compulsory subject in their teacher education course in terms of building the confidence of new teachers to properly prepare them in teaching STEM in their future careers. All these aspects impacting future teachers' STEM visions should be considered and would encourage these teachers to develop educational vision with respect to STEM education. The key issues emerged based on preservice teachers' lack of preparedness and lack of professional development. These are serious issues in terms of teacher preparation in STEM that need to be considered by higher education institutions. Many of the responses were based on their practicum experience (placement in schools) and many reported not seeing many good STEM practices in operation in schools. In this study, we investigated future teachers' backgrounds and their capacity to deal with STEM in their career and identified their beliefs, understandings and intentions to teach STEM using PLS-SEM model. This study provided empirical evidence that Belief has a positive effect on Understanding, and Understanding has a positive effect on Intention.

Future teachers need commitment, confidence and competence in STEM to deal with the challenging and complex demands of 21st century education. The needs and demands of this century including natural resources, energy needs, food habits and ecosystem will impact such STEM challenges. Basic lifestyle changes are required for individuals to cope with the changing and challenging natural systems. Future programs and curriculum needs to generate interest among students by (Falk et al, 2016) and the ecosystem model of STEM (NRC, 2015) for developing and generating integrated program in schools is required. Another key aspect is professional development of STEM for future teachers, which is well argued by Berry et al. (2008) and Lee et al. (2007) for building capacity among teachers to effectively teach this in classrooms.

Conclusions

Our future teachers need more professional development, exposure to better leadership, specialization of STEM practices and procedures and an innovative and integrated approach useful for primary school education. Future teacher preparation needs to encompass skills associated with STEM education that incorporate integration of science, mathematics, engineering and technology, in competency and in practices. Having developed these skills and competencies, the design and implementation of STEM education within schools should be a priority for 21st century learning. They need to feel confident and be well prepared.

If our society wants skilled citizens who can cope with challenges facing us all this century, then governments and higher education institutions and schools need to make STEM a priority.

Limitations

This study achieved the goals that it aimed to investigate. However, there were limitations in this study. We found that the results of assessing the PLS-SEM model were reliable but the validity was not well established. Future research may seek to improve on these areas by looking for more appropriate items regarding Understanding and Intention.

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