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Pongprapan Pongsophon & Benjamin C. Herman

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A theory of planned behaviour-based analysis of TIMSS 2011 to determine factors influencing inquiry teaching practices in high-performing countries

Pongprapan Pongsophon[a] and Benjamin C. Herman[b]

[a]Department of Education, Faculty of Education, Kasetsart University, Bangkok, Thailand; [b]Department of Learning, Teaching and Curriculum, College of Education, University of Missouri, Columbia, MO, USA

ABSTRACT

Given the abundance of literature describing the strong relationship between inquiry-based teaching and student achievement, more should be known about the factors impacting science teachers' classroom inquiry implementation. This study utilises the theory of planned behaviour to propose and validate a causal model of inquiry-based teaching through analysing data relating to high-performing countries retrieved from the 2011 Trends in International Mathematics and Science Study assessments. Data analysis was completed through structural equation modelling using a polychoric correlation matrix for data input and diagonally weighted least squares estimation. Adequate fit of the full model to the empirical data was realised. The model demonstrates that the extent the teachers participated in academic collaborations was positively related to their occupational satisfaction, confidence in teaching inquiry, and classroom inquiry practices. Furthermore, the teachers' confidence with implementing inquiry was positively related to their classroom inquiry implementation and occupational satisfaction. However, perceived student-generated constraints demonstrated a negative relationship with the teachers' confidence with implementing inquiry and occupational satisfaction. Implications from this study include supporting teachers through promoting collaborative opportunities that facilitate inquiry-based practices and occupational satisfaction.

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Inquiry-based teaching; structural equation modelling; theory of planned behaviour; TIMSS

Statement of problems

Inquiry-based teaching has a long storied past informed by work on the nature of learning from Rousseau (1762), Dewey (1910), Piaget (1964), Ausubel (1968), and Vygotsky (1986). These and others' works have informed the development of the constructivist approaches for teaching and learning that are present in contemporary documents that describe reforms-based science instruction (American Association for the Advancement of Science [AAAS], 1989, 1998; Cakir, 2008; Minner, Levy & Century, 2010; National Research Council [NRC], 1996, 1997, 2000). In essence, classroom experiences characterised as scientific inquiry involves teachers facilitating their students to engage in activities

CONTACT Pongprapan Pongsophon pongprapan.p@ku.th Department of Education, Faculty of Education, Kasetsart University, Bangkok 10900, Thailand

and extended investigations that resemble the authentic work of scientists (Anderson, 2002). Salient features of classroom inquiry according to the NRC (1996, 2000) include: (1) engaging students with scientifically oriented questions; (2) helping students to design and conduct investigations in response to those questions; and (3) requiring students to communicate and evaluate their explanations to those questions through using evidence and comparisons to alternative explanations.

A number of studies profile the positive impacts that inquiry-based teaching has on student engagement of the sciences (Minner et al., 2010). Learning through an inquiry approach enables students to deeply contemplate science subject matter, promotes higher-order thinking, and can narrow the persistent achievement gap among diverse groups of students (Anderson, 2002; Flick, 1995; Marshall & Alston, 2014). Many of these instructional outcomes are achieved through students being actively involved with concrete experiences, investigations, and developing science-based explanations with the assistance of their teachers and peers. However, despite the benefits of reforms and inquiry-based science teaching approaches, many teachers opt to implement more traditional practices (e.g. straight lecturing and cookbook laboratories) because of constraints including limited pedagogical abilities, classroom management concerns, and unsupportive school cultures (Bryan & Abell, 1999; Crawford, 2007; Flick, 1995; Herman, Clough, & Olson, 2017; Herman, Olson, & Clough, in press; McGinnis, Parker, & Graeber, 2004).

The Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment projects have demonstrated that teachers in high-performing countries are more likely to adopt inquiry-based teaching in their classrooms (Martin, Mullis, Foy, & Stanco, 2012). However, the factors that influence these teachers' inquiry practices have not been elucidated. This project aims to apply Ajzen's theory of planned behaviour (TPB) to propose and verify a causal model that clarifies the factors that contribute to the inquiry-based teaching efforts in high-achieving countries based on data obtained from the 2011 TIMSS assessments. TIMSS data provide high quality, internationally comparable data because it has a set of standardised operations procedures that all participating countries are expected to follow including sampling, translation verification, data collection, database construction, and the construction of the achievement and context questionnaire scales (Martin & Mullis, 2012). In addition, TIMSS can provide a large data set that is vital in the development of complex models. Like other statistical modelling, the structural equation modelling (SEM) used here relies on rigorous, evidence-focused literature review and good data in testing theory (Jöreskog, 1993; Kline, 2004). The findings of this present study are expected to provide insight to the interactive determinants that help shape the inquiry-based practices of the investigated teachers. Furthermore, these findings should have widespread implications for policies, measures, and guidelines regarding the promotion of inquiry-based science teaching.

Theoretical framework

Theory of planned behaviour

Ajzen's TPB (see Figure 1) provides a framework for explaining a wide variety of intentions and actions including why and how science teachers implement inquiry (Ajzen,

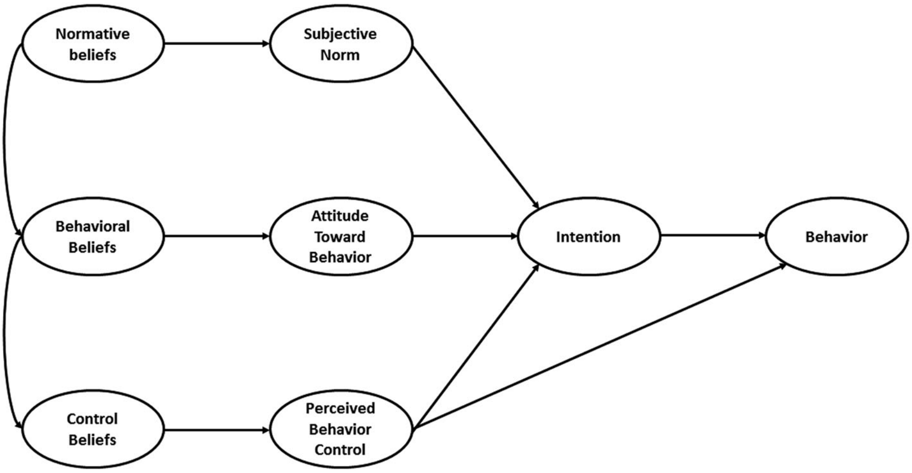

Figure 1. Theory of planned behaviour.

1985; Ajzen & Madden, 1986). According to the TPB, a human behaviour is immediately preceded by the intention to engage in that behaviour. The strength of behavioural intention is predicted, in turn, by three main determinants: subjective norm, attitude toward the behaviour, and perceived behavioural control. These are influenced by three underlying and interrelated determinants: normative belief, behavioural belief, and control belief. Subjective norm entail peoples' perceptions about a behaviour, which are influenced by underlying normative belief about whether those they closely interact with (e.g. family members, friends, and colleagues) would approve of the behaviour, weighted by the motivation to comply with the perceived norms from those social groups. Attitude toward a behaviour is the extent to which individuals view a particular behaviour positively or negatively, braced by behavioural belief that encompass one's weighted perceptions about the outcomes of that behaviour. The degree to which people believe they regulate a particular action is known as perceived behavioural control, which is predicated by their calculated control belief about the facilitators and obstacles to performing a behaviour. Perceived behavioural control is congruent with self-efficacy.

Theoretical application of TPB and occupational satisfaction to inquiry-based teaching

Again, prior literature proposes many barriers impede inquiry-based science teaching to include school culture and classroom management concerns (Bryman & Abell, 1999; Crawford, 2007; Flick, 1995; Herman et al., 2017; McGinnis et al., 2004). TPB provides a theoretical framework that helps explain how these factors shape teachers' intentions and actions regarding implementing inquiry in the classroom. Anderson (2002, p. 2) provides a congruent explanation when describing the day-to-day dilemmas that must be overcome when trying to implement inquiry:

> [m]uch of the difficulty is internal to the teacher, including beliefs and values related to students, teaching, and the purposes of education. Teachers considering new approaches to education face many dilemmas, many of which have their origins in their beliefs and values.

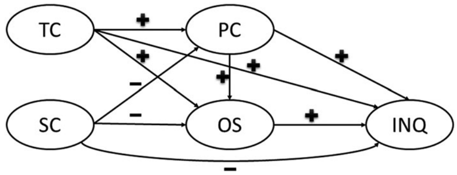

Figure 2. A TPB-based hypothetical causal model of inquiry-based teaching.
Note: TCs: teacher collaborations; SCs: student constraints; PC: pedagogical confidence; OS: occupational satisfaction, and INQ: inquiry practices.

For instance, teachers' subjective norms and belief systems may be influenced through the social interactions they experience in schools. Furthermore, the extent teachers feel that they control classroom activities may be in large part subject to how efficacious they feel with managing student behaviour. Both of these considerations would certainly need to be internally navigated when teachers plan and implement a course of pedagogical action.

The TIMSS 2011 database provides indicator measures for several of the TPB dimensions presented in Figure 1 as they relate to the extent teachers implement inquiry-based practices. This database also provides teachers' responses pertinent to their occupational satisfaction (OS). Presented below and in a proposed model (Figure 2) are descriptions about the TPB dimensions and OS as they are hypothesised in this investigation to relate to teachers' inquiry practices.

Teacher collaboration as a subjective norm

Subjective norm as described by the TPB can manifest through teacher collaborative activities such as curriculum and assessment development and implementation of particular teaching strategies (Midthassel, 2004; Ronfeldt, Farmer, McQueen, & Grissom, 2015). Moreover, sustained teacher collaboration (TC) about instructional strategies can provide a vehicle for continuous improvement of teacher practices through shared accountability and collective responsibility (Herman et al., 2017, in press; McLaughlin & Talbert, 2007; Midthassel, 2004).

Student constraints as a control belief

Teachers' perceived student oriented constraints (SC) are among the most prominent factors that can influence pedagogical practice, whereas teachers attempt to optimise student involvement and behaviour rather than melding theory and practice (Anderson, 2002; Rapport, Denney, Chung, & Hustace, 2001). Constraining factors that teachers may feel the need to mitigate or accommodate include students' financial problems, exceptional needs, misbehaviour, and disinterest. Teachers, school specialists, parents, and administration staffs expend excessive energy on dealing with typically small groups of distracting and defiant students, often with few resulting improvements in either the behaviour or the academic performance of those students. Teachers may experience instructional difficulties, conflict with the child, and conflict with the child's parents, as solutions are sought and strategies discussed. Lack of support from the school and from parents in solving these pressing problems often leads to situations deteriorating and teachers reaching burnout (Friedman, 1995; Soodak, Podell, & Lehman, 1998).

Pedagogical confidence as a perceived behavioural control

Again, perceived behavioural control is congruent with self-efficacy. Self-efficacy refers to the judgments a person makes about their capacity to achieve a certain level of performance (Bandura, 1991). In other words, self-efficacy relates to the extent one can viably control their behaviours in a manner that results in a successful outcome. Delimited to the context of inquiry-based science teaching, it refers to a teacher's pedagogical confidence (PC) about their ability to enact scientific inquiry pedagogy and promote desired outcomes among their students, even if those students are difficult or unmotivated. High levels of teacher efficacy correlate with an increased sense of responsibility and expectations for students' achievement and behaviour. Furthermore, teacher efficacy plays a crucial role in the extent teachers select innovative strategies and persistently navigate barriers to achieving instructional objectives (Bandura, 1993; Soodak et al., 1998).

Occupational satisfaction

The TPB does not entail dimensions directly applicable to gauging how teachers' occupational satisfaction (OS) associates with their implementation of inquiry-based practices. However, teacher OS has been linked to perceived support from administrators and colleagues, availability of school resources, and physical and social working conditions. When teachers perceive a lack of support for their work and decreased OS their classroom practices may suffer (McLaughlin & Talbert, 2007; Southerland, Sowell, & Enderle, 2011). In worst-case scenarios they may leave the school or profession altogether (McGinnis et al., 2004). Given the possible impact of teachers' OS on their inquiry practices, we have included this dimension in our hypothesised model alongside the other TPB-based variables as possible influencers of the investigated teachers' inquiry-based practices.

Research methods

Source of data

This study used data from TIMSS 2011, the latest assessment cycle at the time the study was conducted. The TIMSS project was initiated in 1995 and has been administered by the International Association for the Evaluation of Educational Achievement (IEA) every four years to compare international trends in Grade 4 and Grade 8 students' mathematics and science performance (Martin et al., 2012). Additionally, TIMSS collects data from teachers, school principals, and students' parents on factors (e.g. home, curriculum, classroom, and school characteristics) that may impact student learning. The achievement test and contextual questionnaires in TIMSS were designed and developed by collaborative teams of content experts, science educators, and educational assessment and evaluation experts who represent the participating countries (Martin & Mullis, 2012). TIMSS 2011 included more than 600,000 Grade 4 and Grade 8 students from 52 and 55 participating education systems, respectively. The samples of Grade 8 students and their corresponding teachers in each country were randomly selected using a stratified two-stage cluster sample design. At first, probability proportional to size was utilised to sample a subset of schools from the list of all schools that had eligible students. In such a process, the schools on the list may be stratified according to important demographic variables. The second sampling stage consisted of selecting one or more intact classes from the target grade of each participating school.

Data retrieval, screening, imputation, and descriptive statistics

The TIMSS 2011 data were retrieved from EIA's data repository website. The sample analysed here comprised Grade 8 science teachers from six high-achieving countries; Russia, Finland, Japan, Taiwan, Singapore, and South Korea. Exclusion of cases where imputation of missing values was unsuccessful resulted in a total of 2579 responses (Table 1).

Indicators (manifest variables) were selected from the TIMSS data based on their relevance to the proposed model's constructs (Figure 2). Each model construct was represented by four to six indicators, which were measured using a three- or four-point Likert scale. Using SPSS, the data were prepared, explored, and coded in a manner that higher numerical responses represent higher levels of frequency and agreement (see Table 2 and Appendix A). Missing values were imputed using the expectation-maximisation algorithm. Due to the multiple files relating to the six countries, a syntax process was used to run repeated commands and the files were merged into a single file.

Data analysis

Data were summarised through calculating means, standard deviation, and correlations. Means interpretation was conducted through calculating class intervals and ranges for each scale (see Appendices A and B). Pearson's correlation coefficient was used to measure the strength and direction of the association between the variables. Each correlation coefficient was interpreted as an effect size, with thresholds of .10, .30, and .50, respectively, representing weak, moderate, and strong associations (Cohen, 1988). Correlations between indicators to the same construct should be high, while correlations between theoretically dissimilar measures should be low.

The hypothesised causal model was tested through SEM analysis. SEM analysis generates a structure of the covariance matrix of the measures, and estimates of the model parameters. The implied model is then compared to an empirical covariance matrix to examine whether the two matrices are consistent (Jöreskog, 1993; Kline, 2004). If the model fits the data, the structural equation models can be considered a plausible explanation for correlations between the measures. In the model, manifest variables are used to infer unobservable latent variables. Unbiased estimates for the relationships between the latent constructs are derived because measurement errors are taken into account during SEM analysis.

LISREL 9.2 was used to conduct SEM analysis through the two-step approach suggested by Anderson and Gerbing (1988). First, a measurement model relating manifest variables

Table 1. Number of responses by country.

Countries	Number of responses	Countries	Number of responses
Finland	827	Russia	916
Japan	151	Singapore	330
South Korea	202	Taiwan	153

Table 2. Descriptive statistics from the analysis of individual TIMSS items.

Constructs	Indicators	Mean (SD)	Interpretation
Teacher collaborations (TC; scores: 1 (never) to 4 (daily))	Discussions about teaching topics	2.32 (0.77)	Two or three times/ months
	Planning and preparing materials	2.05 (0.72)	
	Sharing learning experiences from teaching	2.36 (0.77)	
	Trying new ideas together	1.86 (0.65)	
Occupational satisfaction (OS; scores range from 1 (disagree a lot) to 4 (agree a lot))	Content with teaching profession	3.39 (0.63)	Agree a lot
	Satisfied with teaching in my school	3.36 (0.65)	
	Feeling teaching is important work	3.65 (0.52)	
	Plan to continue teaching as long as possible	3.30 (0.74)	
	Feeling frustrated as a teacher	3.18 (0.83)	Agree a little
Student constraints (SC; scores range from 0 (not applicable/absent) to 3 (a lot limiting))	Lacking perquisite knowledge/ skills	1.66 (0.87)	Somewhat limiting
	Lack of sleep	1.43 (0.91)	Not limiting at all
	Exceptional needs (e.g. psychological impairment)	1.23 (0.92)	
	Disruptive students	1.68 (0.85)	Somewhat limiting
	Uninterested students	1.86 (0.71)	
Pedagogical confidence (PC; scores range from 1 (not confident) to 3 (very confident)	Answer students' science questions	2.78 (0.41)	Very confident
	Explain science ideas through experiments	2.75 (0.45)	
	Provide challenging tasks for students	2.55 (0.59)	
	Engage students' interests	2.56 (0.53)	
	Help students value science learning	2.61 (0.53)	
Inquiry practices (INQ; scores range from 1 (never) to 4 (every/almost every lesson))	Observe and describe natural phenomena	2.67 (0.74)	About half the lessons
	Design experiments/ investigations	2.10 (0.66)	Some lessons
	Conduct experiments/ investigations	2.46 (0.72)	Some lessons
	Provide explanations	3.36 (0.75)	Every or almost every lessons
	Relate science to students' lives	3.29 (0.78)	
	Do field work	1.77 (0.56)	Some lessons

to a particular latent variable was tested by means of confirmatory factor analysis. This approach requires examining and demonstrating the construct validity of a measurement model through using convergent and discriminant validity (Jöreskog, 1993; Kline, 2004). Convergent validity tests the relationship between theoretically related constructs, while discriminant validity establishes whether constructs thought to have no relationship are truly unrelated. After a measurement model has been modified to fit the data, the goodness-of-fit indices of the full model are examined.

Yang-Wallentin, Jöreskog, and Luo (2010) strongly suggests model estimation should use polychoric correlations and fit the structural equation models to ordinal data using methods such as unweighted least squares (ULS), maximum likelihood (ML), weighted least squares (WLS), and diagonally weighted least squares (DWLS). Yang-Wallentin et al., (2010) demonstrated these methods yielded consistent parameter estimates, but ULS, ML, and DWLS returned incorrect standard errors. Correct standard errors can be obtained for these methods by means of robustification to make the method less sensitive to the effects of random variability using an estimate of the asymptotic covariance matrix of the polychoric correlations. When used in this way, the methods will be called robust, adding the acronym 'R' to the acronyms 'ULS', 'ML', and 'DWLS'. RDWLS were used in this present study. In this method, input matrices of polychoric correlations and asymptotic covariance were estimated. The RDWLS computes robust chi-squares and subsequent indices by correcting for non-normality. Li (2016) also recommends using RDWLS and RULS when fitting an SEM model with ordinal observed variables. Li demonstrates that compared with ML and robust ML, RDWLS and RULS produce more reliable model inference and small structural relationship detection with data characterised by small-to-medium sample sizes and moderate asymmetries. Here, particular attention was given to comparative fit index ($CFI \geq 0.96$), weighted root mean square residual ($WRMR \leq 1$) and root mean square error of approximation ($RMSEA \leq .05$) indices. These have been found in previous simulation studies to be more trustworthy than other fit indices as indicators of good models with binary outcomes at sample sizes larger than 250 (Finney & DiStefano, 2006; Yu, 2002).

Results

This section presents the results in two parts: the descriptive analysis and the SEM analysis. The SEM analysis starts with findings on the measurement model and is followed by the findings for the full model.

Descriptive statistics

Table 2 presents results from descriptive analyses of individual TIMSS items, which shows that the surveyed participants engaged in TC approximately two to three times each month. Most TC were comprised of sharing what has been learned from teaching experiences, followed by discussions on how to teach specific concepts, preparing instructional materials, and trying out new ideas together. The teachers largely reported a high degree of OS; feeling their work was important, were satisfied with teaching in their schools, and planned to continue teaching for as long as possible. However, the teachers reported being mildly frustrated with teaching. The teachers also cited that their practices were somewhat limited by SC including students' lacking prerequisite knowledge, disruptiveness, and disinterest. However, the surveyed teachers largely felt that exceptional needs students and students' lack of rest were not impediments to their science teaching. The teachers generally expressed high levels of PC regarding their ability to implement inquiry-oriented practices. Specifically, they felt most confident in answering students' questions and using science experiments to teach science ideas. The teachers felt somewhat less confident with helping students value science, devising challenging learning tasks, and engaging students' interest. When responding about their INQ, the teachers reported asking the students to give explanations and relate science to daily life in at least almost every lesson. The teachers required their students to observe and describe natural phenomena in about half of their lessons, and facilitated their students to plan and conduct experiments and experience fieldwork only in some lessons.

Correlations among the indicators

Correlational analysis demonstrated that the variables within the constructs of TC, OS, SC, and PC were positively and moderately correlated ($.30 < r < .60$; $p < .01$). However, the variables within the construct inquiry practices (INQ) exhibited small and positive correlations ($.10 < r < .30$; $p < .01$). The relationship between TC and SC, two exogenous latent variables in the model, was trivial ($r < .10$; $p < .01$). The correlations between the constructs of PC and INQ were small and positive ($.10 < r < .30$; $p < .01$), as were the correlations between PC and OS. Trivial correlations ($r < .10$; $p < .01$) occurred between TC and PC, TC and OS, and INQ and OS. See Appendix B for the correlation matrix and coefficients between all the observed variables.

Measurement model

Convergent validity

Table 3 shows that the measurement models for the constructs of TC, OS, and PC demonstrated a good fit to the data with insignificant chi-square values ($p > .05$) and fit indices approaching the suggested thresholds. All factor loadings exceeded .5 (.64–.89) and demonstrated statistically significance at $p < .01$ (Fornell & Larcker, 1981). This indicates that the items typically represented and measured their associated construct. Given the acceptable composite values (.79–.88, threshold >.70), the convergent validity of these constructs was established. Convergent validity was further evidenced through all of the indicators' standardised loading on the posited latent constructs being more than twice the standard error. The average variance extracted (AVE) of a construct is another evidence of convergent validity, it should be higher than .5 (Fornell & Larcker, 1981). The AVE values of TC and PC were higher than or close to the suggested cutoff point of .50 (.58 and .65, respectively). The AVE value of OS was lower than .50 (.49). Cronbach's α values of the three constructs ranged between .79 and .88, thus demonstrating acceptable reliability.

The measurement model for SC and INQ demonstrated an acceptable fit to the data (Table 3). Although the chi-square values were significant at .05, other fit indices approached acceptable thresholds. All factor loadings of SC exceeded .5 (.56–.83) and were statistically significant ($p < .05$). The composite value was .79, exceeding the limit (.70) that establishes convergent validity. All indicators' standardised loading on the construct was greater than twice the standard error of the construct. However, the AVE value was .49, slightly lower than the suggested cutoff of .50. Cronbach's α for the construct was .80, thus demonstrating acceptable reliability. The convergent validity of INQ could not be established despite demonstrating model fit to the data. Three of the INQ items demonstrated factor loadings below the recommended threshold of .5. The composite value of .64 was lower than the recommended cutoff of .70. The AVE value was .28, far lower than the recommended threshold of .50. Despite the low loadings for the three INQ items, we retained these items for this investigation's analyses because they entail the key attributes of inquiry-based teaching: conducting experiments, providing explanations, and relating science to the real world.

Discriminant validity

According to the Fornell–Larcker testing system (1981), comparing the amount of the construct variance (AVE) and the shared variance with other constructs provides a

Table 3. Factor loadings, Cronbach's *α*, AVE, and composite validity of the constructs derived from the 2011 TIMSS data.

Constructs	Indicators	Std. factor loading	Std. error	*t*-value	Cronbach's *α*	Avg. variance extracted	Composite reliability
Teacher collaborations (TC)	Discussions about teaching topics	Fix	n/a	n/a	.8	.58	.80
	Planning and preparing materials	.89	.03	33.9			
	Sharing learning experiences from teaching	.67	.03	30.38			
	Trying new ideas together	.71	.03	28.44			
χ^2/df = *3.53*, *p* = *.06*, CFI = *0.99*, GFI = *0.99*, SRMR = *.007*, RMSEA = *.06*							
Occupational satisfaction (OS)	Content with teaching profession	Fix	n/a	n/a	.79	.49	.79
	Satisfied with teaching in my school	.8	.03	31.02			
	Feeling teaching is important work	.64	.03	26.41			
	Plan to continue teaching as long as possible	.66	.03	28.56			
	Feeling frustrated as a teacher	.69	.03	29.63			
χ^2/df = *1.85*, *p* = *.13*, CFI = *0.99*, GFI = *0.99*, SRMR = *0.008*, RMSEA = *0.04*							
Student constraints (SC)	Lacking perquisite knowledge/skills	Fix	n/a	n/a	.77	.49	.79
	Lack of sleep	.56	.03	21.61			
	Exceptional needs (e.g. psychological impairment)	.59	.03	24.1			
	Disruptive students	.80	.04	27.92			
	Uninterested students	.83	.04	26.79			
χ^2/df = *3.81*, *p* = *.009*, CFI = *0.99*, GFI = *0.99*, SRMR = *.01*, RMSEA = *.05*							
Pedagogical confidence (PC)	Answer students' science questions	Fix	n/a	n/a	.82	.65	.88
	Explain science ideas through experiments	.8	.03	37.37			
	Provide challenging tasks for students	.87	.04	29.4			
	Engage students' interests	.77	.04	24.5			
	Help students value science learning	.79	.04	27.4			
χ^2/df = *1.34*, *p* = *.26*, CFI = *0.99*, GFI = *1*, SRMR = *.005*, RMSEA = *.06*							
Inquiry practices (INQ)	Observe and describe natural phenomena	Fix	n/a	n/a	.66	.28	.64
	Design experiments/investigations	.68	.08	15.48			
	Conduct experiments/investigations	.36	.07	10.21			
	Provide explanations	.4	.06	12.89			
	Relate science to students' lives	.43	.06	14.77			
	Do field work	.7	.09	14.98			
χ^2/df = *2.34*, *p* = *.03*, CFI = *0.99*, GFI = *0.99*, SRMR = *.01*, RMSEA = *.04*							

Table 4. Correlation between constructs and a construct with its measure.

	Teacher collaborations (TC)	Occupational satisfaction (OC)	Student constraints (SC)	Pedagogical confidence (PC)	Inquiry practices (INQ)
Teacher collaborations (TC)	(.76)				
Occupational satisfaction (OS)	.231	(.7)			
Student constraints (SC)	−.002	−.233	(.7)		
Pedagogical confidence (PC)	.225	.481	−.227	(.8)	
Inquiry practices (INQ)	.319	.222	−.127	.48	(.53)

measure of discriminant validity. The square root values of the AVE for each construct should be greater than the correlation involving the constructs. Table 4 shows the correlation matrix for the constructs. The diagonal elements have been replaced by the square roots of the AVE values. For discriminant validity to be judged adequate, these diagonal elements should be greater than the off-diagonal elements in the corresponding rows and columns. In this case, discriminant validity appears satisfactory, indicating that each construct shares more variance with its items than it does with other constructs.

Full model

The structural model provided an adequate fit to the data ($\chi^2/\mathrm{d}f = 4.97$, $p < .001$, CFI = *0.90*, GFI = *0.90*, SRMR = *.05*, RMSEA = *.07*) (see Figure 3). Maydeu-Olivares and Joe (2014) suggests cutoff criterion for adequate fit with categorical data analysis for RMSEA is .08 and for SRMR is .05. TC demonstrated a positive relationship with OS, PC, and the implementation of INQ ($\beta = .16$, *.22*, and *.22*, respectively; $p < .01$). However, SC negatively impacted the surveyed teachers OS and PC ($\beta = -.18$ and $-.19$, respectively; $p < .01$). PC was found to be the strongest predictor of the investigated teachers' implementation of INQ ($\beta = .54$; $p < .01$) and OS ($\beta = .37$; $p < .01$). The model appears to substantiate the TPB through demonstrating that the teachers' control beliefs about managing SC and collegial collaborations as a vehicle for subjective norms had an indirect effect on the implementation of INQ. The effect of these two variables was mediated by the teachers' PC, which relates to perceived behaviour control in that this variable refers to the teachers' efficacy to implement inquiry-based practices and promote student engagement. PC, along with TC, collectively explained 39% of the variance in the implementation of INQ. These factors, together with SC, could explain the 25% variance in OS.

Discussion

Our SEM analysis of TIMSS 2011 responses from Grade 8 science teachers from the six high-achieving countries of Russia, Finland, Japan, Taiwan, Singapore, and South Korea demonstrates that Ajzen's TPB serves as an informative framework for elucidating teachers' pedagogical intentions and actions (Ajzen, 1985; Ajzen & Madden, 1986). Figure 4 shows an empirically based model that proposes the degree the teachers engaged in collaborations (TC; a source of subjective norm), and exhibited confidence with inquiry-oriented teaching (PC; a perceived behaviour control), positively related with those teachers' implementation of inquiry-based practices (INQ; behavioural outcomes). Student constraints (SC) were postulated as an underlying control belief that indeed

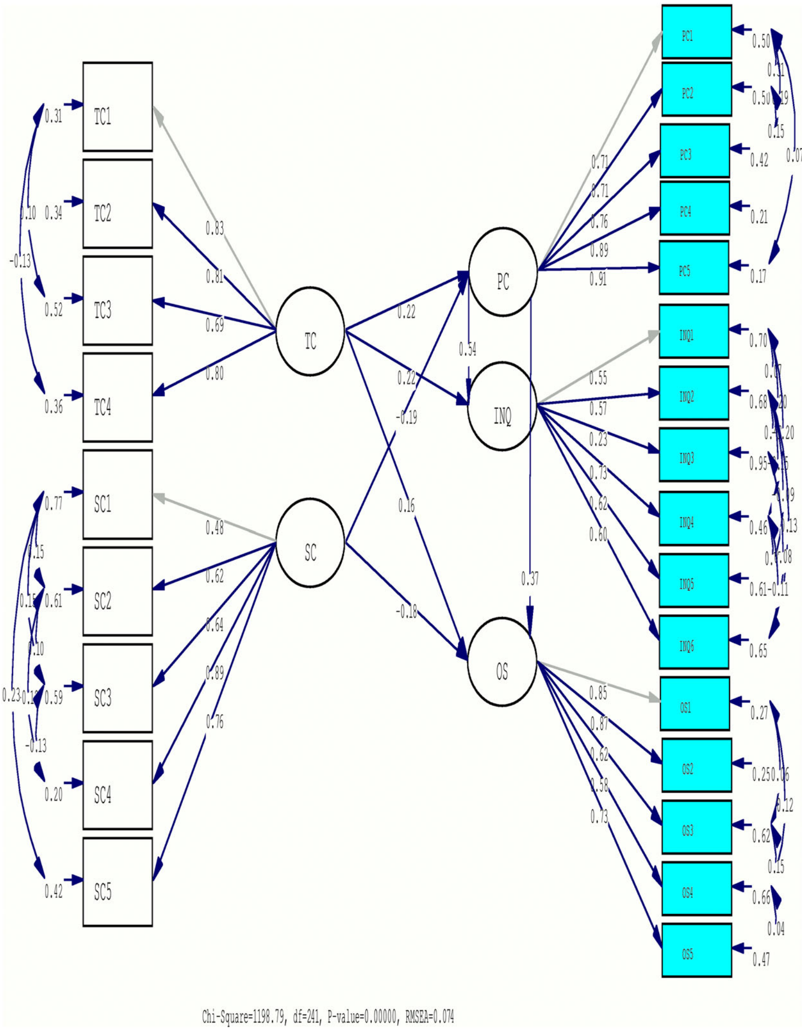

Figure 3. Empirically based model proposing factors that impacted the implementation of inquiry-based practices.

Note: TCs: teacher collaborations; SC: student constraints; PC: pedagogical confidence; OS: occupational satisfaction, and INQ: inquiry practices.

demonstrated a negative effect on teachers' PC with implementing INQ and occupational satisfaction (OS). However, SC did not have a significant direct relationship with the teachers' reported INQ. For this reason, the hypothesised explicit link

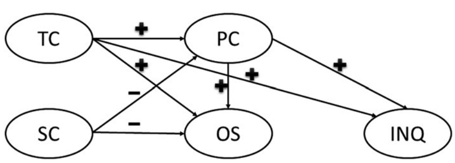

Figure 4. Validated full model of inquiry-based teaching.

between SC and INQ was deleted from the final model. Consistent with our hypothesised model, our empirical results indicate that the teachers' perceptions of SC and TC involvement were together mediated through the teachers' PC with implementing inquiry to impact those teachers' enacted INQ and OS. Results from this investigation also demonstrated that the teachers' OS and INQ were not related. This aligns with previous work that indicates teachers can possess diverse epistemic and pedagogical beliefs and approaches regarding teaching and learning, yet feel positive about their occupation (Glasson & Lalik, 1993; Palmer, 2005). Similarly, the Teaching and Learning International Study (TALIS), which investigated secondary teachers and principals from schools in 24 countries, showed that teachers who adopted and implemented a constructivist inquiry approach to teaching and teachers who held and enacted a direct transmission view (i.e. traditional teaching approach) guided by curricular requirements and standardised tests expressed similar job satisfaction (Organization for Economic Co-operation and Development [OECD], 2009). Conclusively, ensuring teachers' occupational satisfaction alone appears insufficient for guaranteeing the implementation of inquiry-based teaching practices.

The investigated teachers reported only collaborating an average of two to three times a month with trying out new instructional ideas together receiving the least of their attention. These findings are consistent with those of the TALIS which demonstrated that teachers in all of the investigated countries more commonly engaged in exchanging and coordinating ideas and information rather than more direct forms of professional collaboration, such as team teaching, observing another's instruction and providing feedback, and collaborative work on research and innovation. It was explained in the TALIS report that collaborative activities were influenced by school leadership and teacher evaluation policies, and by national pedagogical traditions.

Our analyses showed that even moderate amounts of collaboration between teachers has a positive relationship with PC and that, in turn, may facilitate INQ and OS. These findings can be explained through social cognitive theory. Specifically, Bandura (1991, 1993) proposed that there are four sources of information individuals employ to judge their abilities and self-efficacy. Two of which, vicarious experience and social persuasion, can be facilitated and enhanced through collaboration in a community of like-minded professionals. Vicarious experience is realised when a person judges their competency based on observing the modelling of another. Increases in self-efficacy and confidence may be realised when people perceive through these vicarious experiences that their performance matches that of successful others. Social persuasion can also encourage self-efficacy and confidence with performance through supportive encouragement, accountability, and constructive feedback. The modelling and collegial support from like-minded and respected peers has been noted to be a crucial factor for promoting teachers' self-assessment and reflective implementation of inquiry-based practices. Furthermore, such collegial social supports have been shown promote lower levels of stress, better constraint-coping mechanisms, and higher levels commitment and job satisfaction among teachers (Caprara, Barbaranelli, Steca, & Malone, 2006; Herman et al., 2017, in press; Klassen, 2010; Klassen & Chiu, 2010; OECD, 2009). Clearly, the science education field should look to bolster efforts toward establishing effective teacher mentorship and support among those that deeply advocate research-based science teaching practices in the interest of promoting classroom inquiry and teacher retention.

Significant and comparably strong net effects of PC on OS were realised among the teachers investigated here . However, while the teachers exhibited confidence with implementing inquiry-oriented practices, their actual reported practices appeared tepid regarding several key inquiry features. Specifically, the teachers investigated in this study reported some to half of their lessons require students observe and describe natural phenomena, plan and conduct experiments, and engage in fieldwork. One possible explanation regarding the mismatch between the teachers' OS, PC, and their actual practice is that teachers may feel able to implement inquiry, but willingly eschew those practices because of constraints. Several have discussed key roadblocks to creating collaborative and supportive professional school cultures that promote reform-based instruction (Herman et al., in press; Ihrig, Clough, & Olson, 2014; McGinnis et al., 2004; McLaughlin & Talbert, 2007). These include time constraints, community and school cultural expectations resistant to educational reforms efforts, and teacher isolation. Another explanation for this mismatch can be attributed to the inherent complexities of enacting highly effective inquiry science instruction. Such instruction is very demanding and requires teachers to deeply understand the content they teach, student cognition, and how to implement planned and spontaneous classroom experiences consistent with recommendations from educational research (Clough, Berg, & Olson, 2009; Herman, Clough, & Olson, 2013). Work on expertise psychology states that people often use ill-informed and preconceived premises to embellish their abilities in areas they lack skill. Conversely, those who are highly competent in a particular domain tend to underestimate their abilities in that domain (Dunning, Johnson, Ehrlinger, & Kruger, 2003). Others (e.g. Herman et al., 2017) have demonstrated teachers exhibiting the highest confidence in their pedagogical abilities are often unaware of the deficiencies in their practice and maintain they are doing a fine job. This later explanation may help explicate why many of the teachers in this study maintained high degrees of PC and OS despite their limited inquiry practices. Given the difficulties associated with implementing inquiry science teaching in current school cultures, and that many teachers are ill equipped to implement such efforts, may explain why those practices are often lacking in K-12 settings (Crawford, 2007).

Limitations of this study become evident when considering the mismatch between the investigated teachers' PC and their actual reported practices. These limitations largely stem from the inability to align the TIMSS 2011 data with some of the TPB dimensions. For instance, TIMSS 2011 data do not permit insight into the teachers' intentions that motivate their practices, which caused us to omit this dimension from our hypothesised model. Central to the TPB, intention mediates subjective norm, perceived behavioural control, and attitude to determine one's actions (Ajzen, 1985; Coladarci, 1992). Without our ability to closely analyse this variable several questions remain regarding the factors that determine teachers' inquiry implementation. For instance, teachers could lack motivation and intention to implement inquiry if they perceive doing so requires extensive effort. Also, relating to previous issues regarding expertise and collegiality, it could be that teachers fully intend to implement inquiry but lack the self-reflection abilities, knowledge bases, and support to do so. Another, limitation of this study relates to the extent TIMSS 2011 data enables measuring perceived behavioural control. According to Ajzen (2002) and Rhodes and Courneya (2003), perceived behavioural control comprises both self-efficacy and controllability over performance of a behaviour of interest. TIMSS

2011 data provide insight into teachers' pedagogical self-efficacy, but not their perceived control over their teaching performance. Therefore, this study treated the teachers' reported PC (self-efficacy) as the sole indicator of perceived behavioural control. Other studies have indicated that the extent teachers feel in control of their pedagogical performance may play an important role in their implemented classroom practices. For instance, in a large-scale study involving 12 countries, Dorier and Garcia (2013) analysed the conditions facilitating and impeding the implementation of inquiry-based mathematics and science education practices. This investigation showed that the first priority for many teachers was to deliver the entirety of the listed curriculum content. Other factors that appeared to control the investigated teachers' performance expectations included national assessments and resistance to inquiry-based teaching from students and parents. These factors appeared to constrain the teachers' inquiry implementation despite their possessing positive attitudes and motivations toward enacting those practices. More broad scale and comprehensive studies are needed that employ nuanced facets of the TPB to help explain the intentions and practices of science teachers. Furthermore, investigations are needed that provide multi-group comparisons of the pedagogical intentions and practices occurring among teachers from high, medium, and low achieving countries.

Implications

The findings from this study demonstrate that collaborations among teachers can promote their PC, which facilitates implementing inquiry. While SC negatively impact PC, this confidence serves as a mediator for inquiry practice. This investigations' findings provide implications for augmenting teachers' collaborative efforts, such as professional learning communities (PLC), through insights from the TPB. Here we frame PLC's as an ongoing, reflective, and collaborative progress through which educators share learning and critically interrogate their practice and enhance their effectiveness for students' benefit (Hord, 1997; McLaughlin & Talbert, 2007; McREL, 2003). Principles of PLC include norms of collaboration, focus on students and their academic performance, access to a wide range of learning resource for individuals and the group, and mutual accountability for students' growth and success (Hord, 1997; Louis & Marks, 1998; McLaughlin & Talbert, 2007). The methods used to accomplish these goals are diverse and varied (Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013), including but not limited to lesson study, collaborative action research, and the adoption, adaption, and evaluation of new curriculum standards. Several studies (Lakshmanan, Heath, Perlmutter, & Elder, 2011; Lewis, 2002; Puchner & Taylor, 2006; Sibbald, 2009) examined the effect of a sustained PLC-oriented programme on teacher's self-efficacy with implementing inquiry-based teaching. These studies employed principles of PLC and Bandura's source of information for self-efficacy as a framework for designing a professional development programme. The studies indicated that PLC could increase the participant's self-efficacy and inquiry teaching practices.

The goals and structure of collaborative initiatives such as PLC's should not only promote teachers' constraint-coping strategies and self-efficacy for implementing inquiry-based teaching. These collaborations must also tap into teachers' existing belief systems about what constitutes effective science education, as these beliefs undoubtedly influence the extent teachers successfully implement science as inquiry (Anderson, 2002; Bryan, 2003; Crawford, 2007; Herman et al., 2017; Lam, Yim, & Lam, 2002). The development of teaching beliefs and their facilitation to classroom practice largely depends on the norms and expectations teachers develop about education through their own experiences as students, as professional development participants, with science teaching curriculum and materials, and within the workplace culture set forth by principals, mentors, students, parents, and others. Unfortunately, the many years of experiences teachers have with science teaching and learning overwhelmingly espouse and entrench beliefs that are in favour of traditional practices. Given these belief systems are complex and nested, they shape teaching decisions and are resistant to modification despite numerous encounters with knowledge and examples that promulgate effective inquiry-oriented science teaching (Bryan, 2003; Bryan & Abell, 1999; Wallace & Kang, 2004). For instance, Herman et al., (2013, 2017, in press) investigated 13 science teachers 2–5 years after completing the same intensive reforms-based science teacher preparation programme and demonstrated that those teachers' nature of science (NOS) and inquiry instruction was associated with their utility value for such instruction, epistemological beliefs regarding constructivist and social learning theories, and abilities to critically self-reflect about teaching. Four of the 13 teachers became isolated from others who completed that programme and at the time of the study exhibited beliefs about teaching and enacted practices that were overwhelmingly traditional and didactic. The remaining nine teachers implemented NOS and inquiry effectively and exhibited beliefs consistent with these practices, largely because they regularly engaged in supportive collaborations with one another long after completing their science teacher preparation programme.

PLC-oriented lesson study approaches may help teachers develop the norms, attitudes, beliefs, and intentions consistent with implementing inquiry-based teaching (Lewis, 2002). Lesson study approaches must be iterative and create a culture where teachers collaboratively reflect not only on their practices, but also their rationales behind those practices. A complete lesson study cycle could consist of: (1) collaborative lesson research, design, and preparation, (2) implementation by one teacher while colleagues observe, (3) supportive and reflective discussion and revision among the collaborative group, (4) implementation of the revised lesson by a different teacher from the study group while colleagues observe, and (5) supportive and reflective discussion and revision among the collaborative group. These steps should be repeated until the lesson exhibits a high degree of congruence with inquiry and reforms-based practices that promote students' deep conceptual science engagement.

In the lesson study, teachers should collaborate with their colleagues at all stages under the supervision of PLC administrators that can work with teachers to build subjective norms consistent with creating a culture exemplified by reforms-based inquiry practices. Through these prolonged collaborations the teachers' confidence in inquiry-based teaching can be enhanced because they are developing mastery experience through researching, designing, and reflectively implementing their ideas in real classrooms with the support of other capable peers. Furthermore, they gain vicarious experience when they observe those peers successfully implement the collaboratively constructed lessons. Importantly, lesson study teams can augment their participating teachers' sense of perceived behaviour control and abilities to handle constraints. For instance, when teachers are confronted with the challenges and difficulties that so often occur in classrooms, they can get assistance, advice, constructive feedback, encouragement, and emotional support from their teammates in the learning community.

A cautionary note should be expressed regarding PLC's and other collaborative efforts intended to impose a particular set of subjective norms. Several have written about how reform-oriented teachers, particularly in the beginning stages of their career, have had their best intentions of implementing inquiry-based practices stifled by the cultures in schools set forth by mentors, administrators, and others who favour traditional practices (Herman et al., in press; Ihrig et al., 2014; McGinnis et al., 2004). Therefore, despite the best of intentions, compulsory instrumental social networks such as PLC's may negatively influence teachers' practices if those networks' norms are at odds with reforms-based science instruction. In these instances, teachers have the choice of capitulating to the groups' expectations, isolating themselves from the group, seeking supports elsewhere, or leaving the school or profession (Ihrig et al., 2014; McGinnis et al., 2004). To ensure collaborative initiatives that draw from frameworks such as TPB express desired outcomes, including inquiry implementation, we recommend the key leaders of such initiatives passionately hold a unified vision for teaching and learning closely congruent with reforms-based science instruction (NRC, 1996, 2000).

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix A: TIMSS measures, scoring ranges, and guidelines for interpretation

Constructs	Indicators	Min, Max, # of classes	Class interval	Range	Interpretation
Teacher collaboration	Discussions about teaching topics	1, 4, 4	0.75	1.00–1.75	Never or almost never
	Planning and preparing materials			1.76–2.51	2 or 3 times/month
	Sharing learning experiences from teaching			2.52–3.27	1–3 times/week
	Trying new ideas together			3.28–4.00	Daily or almost daily
Occupational satisfaction	Content with teaching profession	1, 4, 4	0.75	1.00–1.75	Disagree a lot
	Satisfied with teaching in my school			1.76–2.51	Disagree a little
	Feeling teaching is important work			2.52–3.27	Agree a little
	Plan to continue teaching as long as possible			3.28–4.00	Agree a lot
	Feeling frustrated as a teacher				
Student constraints	Lacking perquisite knowledge/skills	0, 3, 4	0.75	0.00–0.75	Not applicable/absent
	Lack of sleep			0.76–1.51	Present/not limiting
	Exceptional needs (e.g. psychological impairment)			1.52–2.27	Present/somewhat limiting
	Disruptive students			2.28–3.00	Present/a lot limiting
	Uninterested students				
Pedagogical confidence	Answer students' science questions	1, 3, 3	0.67	1.00–1.67	Not confident
	Explain science ideas through experiments			1.68–2.35	Somewhat confident
	Provide challenging tasks for students			2.36–3.00	Very confident
	Engage students' interests				
	Help students value science learning				
Inquiry practice	Observe and describe natural phenomena	1, 4, 4	0.75	1.00–1.75	Never
	Design experiments/ investigations			1.76–2.51	Some lessons
	Conduct experiments/ investigations			2.52–3.27	About ½ lessons
	Provide explanations			3.28–4.00	Every or almost every lesson
	Relate science to students' lives				
	Do field work				

Appendix B: Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	2	13	14	15	16	17	18	19	20	21	22	23	24	25
TC1																									
TC2	.58**																								
TC3	.59**	.49**																							
TC4	.43**	.52**	.43**																						
PS1	.11**	.07**	.09**	.14**																					
PS2	.15**	.08**	.11**	.18**	.63**																				
PS3	.10**	.02	.10**	.13**	.43**	.38**																			
PS4	.09**	.05**	.05*	.09**	.50**	.40**	.38**																		
PS5	.12**	.07**	.10**	.10**	.52**	.51**	.32**	.38**																	
SC1	.01	.00	.03	−.01	−.09**	−.13**	−.03	−.05*	−.12**																
SC2	.05*	.01	.06**	−.07**	−.08**	−.17**	−.05**	−.07**	−.16**	.37**															
SC3	.01	.00	.04	.01	−.09**	−.11**	−.01	−.03	−.09**	.38**	.42**														
SC4	.00	.01	.01	.00	−.13**	−.17**	−.05**	−.09**	−.16**	.36**	.36**	.38**													
SC5	−.03	−.04*	.00	−.01	−.11**	−.15**	−.02	−.09**	−.17**	.50**	.38**	.40**	.59**												
PC1	.05**	.06**	.05*	.19**	.11**	.18**	.20**	.07**	.16**	−.02	−.15**	−.07**	−.02	.01											
PC2	.08**	.07**	.06**	.19**	.12**	.19**	.21**	.08**	.16**	−.06**	−.16**	−.08**	−.05**	−.02	.62**										
PC3	.05**	.04	.05*	.20**	.17**	.22**	.19**	.12**	.21**	−.10**	−.20**	−.10**	−.12**	−.09**	.51**	.50**									
PC4	.05*	.06**	.05**	.21**	.22**	.25**	.25**	.15**	.26**	−.13**	−.24**	−.09**	−.11**	−.12**	.42**	.43**	.52**								
PC5	.06**	.06**	.07**	.20**	.18**	.25**	.26**	.13**	.26**	−.13**	−.22**	−.06**	−.05**	−.07**	.51**	.47**	.52**	.64**							
INQ1	.18**	.13**	.16**	.10**	.09**	.08**	.07**	.07**	.06**	−.02	.04	.01	−.01	−.03	.09**	.11**	.13**	.12**	.13**						
INQ2	.14**	.18**	.11**	.23**	.08**	.07**	.02	.08**	.06**	−.06**	−.10**	−.07**	−.10**	−.09**	.19**	.25**	.21**	.17**	.16**	.31**					
INQ3	.22**	.17**	.17**	.06**	.08**	.04**	.00	.06**	.04	−.01	.05*	−.06**	−.07**	−.09**	−.01	.15**	.06**	.01	−.03	.28**	.49**				
INQ4	.08**	.12**	.09**	.20**	.09**	.12**	.14**	.08**	.12**	−.13**	−.18**	−.07**	.02	−.06**	.26**	.25**	.28**	.30**	.32**	.15**	.19**	.11**			
INQ5	.11**	.11**	.13**	.19**	.10**	.10**	.14**	.10**	.09**	−.08**	−.07**	−.04*	−.02	−.06**	.18**	.16**	.22**	.25**	.25**	.30**	.21**	.14**	.49**		
INQ6	.12**	.15**	.12**	.19**	.09**	.13**	.12**	.06**	.12**	−.07**	−.08**	−.01	−.06**	−.08*	.19*	.21**	.23**	.23**	.23**	.27**	.37**	.17**	.22**	.23**	

Note:*,** correlation is significant at the .05 and .01 levels (two-tailed) respectively.