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Modelling Mathematics Teachers' Intention to Use the Dynamic Geometry Environments in Macau: An SEM Approach

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ABSTRACT

Dynamic geometry environments (DGEs) provide computer-based environments to construct and manipulate geometric figures with great ease. Research has shown that DGEs has positive impact on student motivation, engagement, and achievement in mathematics learning. However, the adoption of DGEs by mathematics teachers varies substantially worldwide. This paper described Macau secondary schools teachers' intention to use DGEs within the theory of planned behaviour (TPB). Using the structural equation modelling approach, results revealed that subjective norm and perceived behavioural control were significant positive predictors of intention, while attitude was not. Further, perceived behavioural control had a significant and positive influence on teachers' attitudes, whereas subjective norm did not. Implications for theory and practice were given.

Keywords

Theory of planned behaviour, Teachers' intention, Dynamic Geometry Environments, Macau

Introduction

Technology is important to the process of teaching and learning of Mathematics (National Council of Teachers of Mathematics [NCTM], 2000). It increases teachers' productivity in teaching and engages students in their learning of mathematics (Pierce & Ball, 2009). Thus, calls for the integration of technology in mathematics education have been made in various educational systems as seen in their official curriculum documents (Curriculum and Development Council & Hong Kong Examination and Assessment Authority, 2007; Curriculum and Planning Division, 2012; NCTM, 2000). Thus far, educational systems in the Western nations have responded to the call more rapidly than those in the East such as Hong Kong and Mainland China (Wong, 2003). In recent years, Macau, a special administration region of China, has become active in promoting technology integration in mathematics education among schools and encouraging teachers to use technology in the classroom. Dynamic geometry environments (DGEs) emerge as a technological tool to support mathematical teaching and learning and it has been integrated in the mathematics classroom in various countries (NCTM, 2000). Given its affordances in shaping mathematics education, the sole teacher education provider in Macau, University of Macau, has recently revised its curriculum to incorporate the use of DGEs into the pre-service and in-service courses.

Dynamic Geometry Environments (DGEs)

Dynamic Geometry Environments (DGEs) are tools originally designed for learning geometry in the 1990s. Nowadays, DGE has evolved to include features that can be used in teaching various subjects such as algebra, calculus and statistics. It provides a computer-based environment in which geometric figures can be constructed and manipulated with great ease (Straesser, 2002). In DGEs, users manipulate geometric figures using a visual interface and receive constructive feedback. In addition, multiple representations of the mathematical objects could be linked dynamically (Laborde, 2007). Using DGEs, teachers could represent and manipulate mathematical objects much more easily than before. Research on DGEs provided evidence in support of its ability to transform mathematics teaching and learning. These included the ability of DGEs to facilitate discovery or inquiry-based instruction (Laborde, 2007), to scaffold geometric problem solving (Straesser, 2002), such as using an inductive approach to explore and investigate mathematical proof, which are not usually achievable within a limited time span (Laborde, 2007). In doing so, students develop their higher-order thinking.

However, the use of DGEs in teaching mathematics is not without limitations (Anthony & Clark, 2011). An example is the low adoption of DGEs among teachers. In order to integrate DGEs into the classroom effectively, teachers have to change the existing mindsets and practices. Essentially, teachers have to learn how to use a new tool, spend more time in designing technology-based tasks to engage students in learning, and revamp their assessment protocols to be compatible with existing standards (Chan, 2015). These reasons could account for the low adoption rate among teachers who would merely use the DGEs as a supplementary tool instead of exploiting its affordances to facilitate students' learning (Ruthven, Hennessy, & Deaney, 2008).

Theory of Planned Behaviour (TPB)

Many models exist that describe and predict the use of technology, such as the Technology Acceptance Model (TAM) (Davis, Bagozzi, & Warshaw, 1989) and Theory of Planned Behaviour (TPB) (Ajzen, 1991). Among these models, the TPB has been used extensively, which assumes that the decision-making process of performing behaviours in a new situation is determined by one's behavioural intentions, which in turn is affected by three major variables: attitude towards the behaviour, subjective norms, and perceived behavioural control. In addition to the direct influence of the three determinants on intention, research has also shown that subjective norm and perceived behavioural control have a direct influence on individuals' attitude towards technology (Teo, Lee, & Chai, 2008; Bellone & Czerniak, 2001).

In this study, a total of four variables were examined. Behavioural intention (BI) and attitudes towards the behaviour (ATT) are the two endogenous variables. ATT is a personal variable which is a person's overall judgment of the behaviour. The judgment comprised beliefs about the consequence of the behaviour which might be positive or negative, and the evaluation of such belief regarding the appropriateness of the behaviour. Another variable in the TPB, subjective norm (SN), refers to the extent one believes that the significant personnel around him or her would support or disapprove a particular behaviour; in this case, the use of DGEs in class. If the person significant to the teacher is supportive of using DGEs in class, the motivation for the teacher to adopt that behaviour would be greater. The third variable, perceived behavioural control (PBC) refers to the extent to which a person feels capable of enacting a behaviour. This belief includes both internal and external constraints or resources that influence one's behaviour. For example, when teachers consider themselves fluent in the use of DGEs, they would tend to perceive greater control of using this tool in class.

Researchers have made the effort to investigate the intention to use of DGEs in classrooms using the TPB model. For example, Stols and Kriek (2011) conducted an exploratory study on 22 mathematics teachers to examine their beliefs and intention to use DGEs. They found that teachers' perceived usefulness and their level of technological proficiency were the most important predictors of their intention to use such technology.

Moderating effects

From the literature, several demographic variables have been identified to have acted as moderators between the intention to use technology and its key determinants. In this study, we focused on age, gender, years of teaching, and technology experience as potential moderators by examining possible differences in the key determinants of technology use intention by teacher profiles.

Age

Prensky (2001) argued that teachers' intention to use of technology varied by their age. For example, those born after 1980, labeled as "digital natives," had grown up surrounded by technology and therefore were more comfortable in using it than those who were born earlier, labeled as "digital immigrants." While the digital immigrant teachers struggle to learn and use technologies and are thus reluctant to adopt them, digital native teachers would face with fewer problems with technology integration (O'Bannon & Thomas, 2014). It is possible that ATT and PBC in technology use would be moderated by age. Furthermore, age was also found to moderate the relationship between subjective norms and behavioral intention, with the relationship stronger for older users (Wang, Wu, & Wang, 2009). On this ground, we expected a stronger effect of ATT and PBC on technology use intention for younger teachers than for older teachers, whereas a stronger effect of SN on technology intention for older teachers.

Gender

In several studies, gender has been found to have a moderating effect on the relationship between behavioral intention and its determinants. For example, females were found to be more significantly influenced than males by attitude when making decisions toward technology-based services (Zhu & Chang, 2014). Gender also affects the relationship between social influences and behavioral intention with a stronger effect for women (Huang, Hood, & Yoo, 2013). As such, we expected a stronger effect of PBC on intention to continue using DGEs for male teachers than for female teachers, whereas a stronger effect of ATT and SN on technology intention for female teachers.

Teaching experience

Teaching experience has been found to be strongly associated with teachers' attitudes and perceptions toward technology usage (Jimoyiannis & Komis, 2007), with more experienced teachers showing more negative attitudes than less experienced teachers (Anderson & Williams, 2012). Further, teachers with less teaching experience reported higher levels of self-efficacy in regards to technology (Kemp, 2002). As these are significant variables in determining their intentions to use technology, teaching experience would also play a role in teachers' technology intention. Hence, we expected a stronger effect of ATT, PBC and SN on intention to continue using DGEs for teachers with less experience than for those with more experience.

Technology experience

Empirical evidence has demonstrated that technology experience moderates the relationship between key determinants of behaviour intention and technology use intention, such that attitude toward behaviour was more salient with increasing technology experience (Taylor & Todd, 1995) and the subjective norm becomes less important with increasing levels of experience (Venkatesh, Morris, Davis, & Davis, 2003), when predicting technology use intention. Hence, we expected a stronger effect of ATT and PBC on intention to continue using DGEs for teachers with more technology experience and a stronger effect of SN on intention to continue using DGEs for teachers with less technology experience.

The present study

Given that DGEs have the potential to foster more effective teaching and learning of mathematics, it is important to understand the impetus of mathematics teachers' intentions to continue the use of DGEs (Ertmer, 2005). This study aimed to examine Macau secondary school teachers' intention to use DGEs in the mathematics classroom and it contributes to the current literature in four ways. First, although the TPB has been applied to examine teachers' intention to use technology in many studies (e.g., Sadaf, Newby, & Ertmer, 2012), these were typically related to general computing such as computer, PowerPoint or Web 2.0. According to Ajzen (2006), further examination of the predictive powers of the TPB model should be conducted with specific behaviours. Second, a limited number of empirical studies has been conducted to examine the use of TPB to understand teachers' intention to use DGEs (e.g., Chan, 2015; Stols & Kriek, 2011). Third, the current study could shed light on the cross-cultural validity of the TPB. Macau is characterized by an educational system highly influenced by Confucian values where examinations drive both teaching and learning (Morrison & Tang, 2002). Results from this study would have strong implications for exam-oriented classrooms. Finally, we adopted the structural equation modelling (SEM) approach in the current study, in contrast to the mainly descriptive, correlation statistics, and regression analysis in existing studies. SEM is useful for analysing the relationships between latent and observed variables, with random errors in the observed variables estimated directly. This is not possible with traditional techniques (e.g., multiple regression). Consequently, SEM produces more precise measurements of the constructs in research (Teo & Zhou, 2014).

The following questions guide this study:

- To what extent is the TPB a valid model to predict mathematics teachers' intention to continue using DGEs?
- What direct and indirect effects do the TPB constructs have on mathematics teachers' intention to continue using DGEs?

- In what way is the relationship between the intention to continue using DGEs and its key determinants moderated by teachers' age, gender, teaching experience, and technology experience?

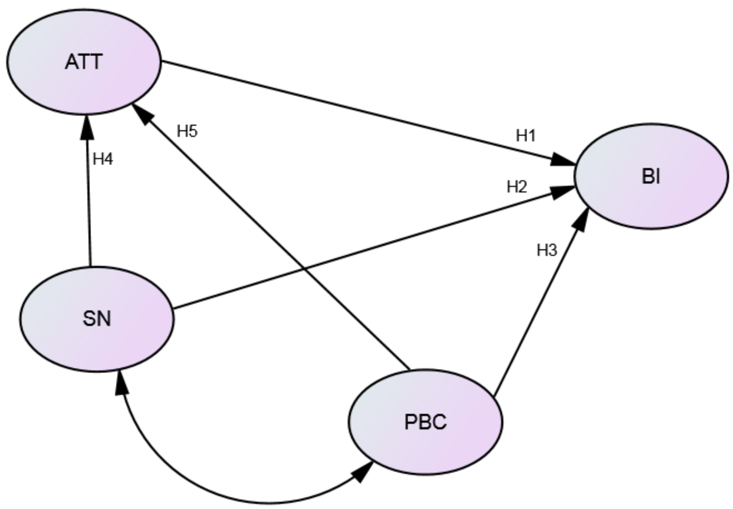
From the above discussion of related literature, the following hypotheses were formulated:

H1: ATT has a direct and significant influence on teachers' intention to continue using DGEs in teaching mathematics
H2: SN has a direct and significant influence on teachers' intention to continue using DGEs in teaching mathematics
H3: PBC has a direct and significant influence on teachers' intention to continue using DGEs in teaching mathematics

Research has also shown that SN and PBC have a direct influence on ATT of the individual (Teo et al., 2008). Hence, the following hypotheses were also tested.

H4: SN has a direct and significant influence on teachers' ATT.
H5: PBC has a direct and significant influence on teachers' ATT.

Figure 1 summarizes the hypotheses proposed in this study.



ATT=Attitude; SN=Subjective Norm; PBC=Perceived Behavioural Control; BI=Behavioural Intention
Figure 1. Proposed research model

In addition, the moderating effects of gender, age, years of teaching and technology experience on the relationships depicted in the model are well supported in the literature as reviewed above. Hence, the following hypotheses were tested:

H1a: ATT influences teachers' intention to use DGEs more strongly for younger teachers than for older teachers.
H2a: SN influences teachers' intention to use DGEs more strongly for older teachers than for young teachers.
H3a: PBC influences teachers' intention to use DGEs more strongly for younger teachers than for older teachers.
H4a: SN influences teachers' ATT more strongly for older teachers than for younger teachers.
H5a: PBC influences teachers' ATT more strongly for younger teachers than for older teachers.

H1b: ATT influences teachers' intention to use DGEs more strongly for female teachers than for male teachers.
H2b: SN influences teachers' intention to use DGEs more strongly for female teachers than for male teachers.
H3b: PBC influences teachers' intention to use DGEs more strongly for male teachers than for female teachers.
H4b: SN influences teachers' ATT more strongly for female teachers than for male teachers.
H5b: PBC influences teachers' ATT more strongly for male teachers than for female teachers.

H1c: ATT influences teachers' intention to use DGEs more strongly for less experienced teachers than for more experienced teachers.
H2c: SN influences teachers' intention to use DGEs more strongly for less experienced teachers than for more experienced teachers.
H3c: PBC influences teachers' intention to use DGEs more strongly for less experienced teachers than for more experienced teachers.
H4c: SN influences teachers' ATT more strongly for less experienced teachers than for more experienced teachers.
H5c: PBC influences teachers' ATT more strongly for less experienced teachers than for more experienced teachers.

H1d: ATT influences teachers' intention to use DGEs more strongly for teachers with more technology experience than teachers with less technology experience.
H2d: SN influences teachers' intention to use DGEs more strongly for teachers with less technology experience than teachers with more technology experience.
H3d: PBC influences teachers' intention to use DGEs more strongly for teachers with more technology experience than teachers with less technology experience.
H4d: SN influences teachers' ATT more strongly for teachers with less technology experience than for teachers with more technology experience.
H5d: PBC influences teachers' ATT more strongly for teachers with more technology experience than for teachers with less technology experience.

Method

Participants and procedure

A survey design was used in this study. An invitation letter was sent to the principals of all 35 secondary schools in Macau where Chinese was used as the medium of instruction. The letter introduced the purpose of the questionnaire and invited mathematics teachers to take part in this study. The link of the online survey was emailed to the mathematics department head in each school who was responsible for sharing the link with all other mathematics teachers in the department. A total of 171 mathematics teachers voluntarily completed an online survey, while 19 completed a paper version of the survey due to a lack of access to the Internet at the point of completing the questionnaire. This led to a total of 190 participants in this study, representing 40% of the whole population of mathematics teachers (475) in Macau at the time of data collection. The survey consisted of two sections (1) demographic information of the participants and (2) items designed to measure teachers' intention to use DGEs in class (in this study GeoGebra was promoted to Macau teachers, see Figure 2).

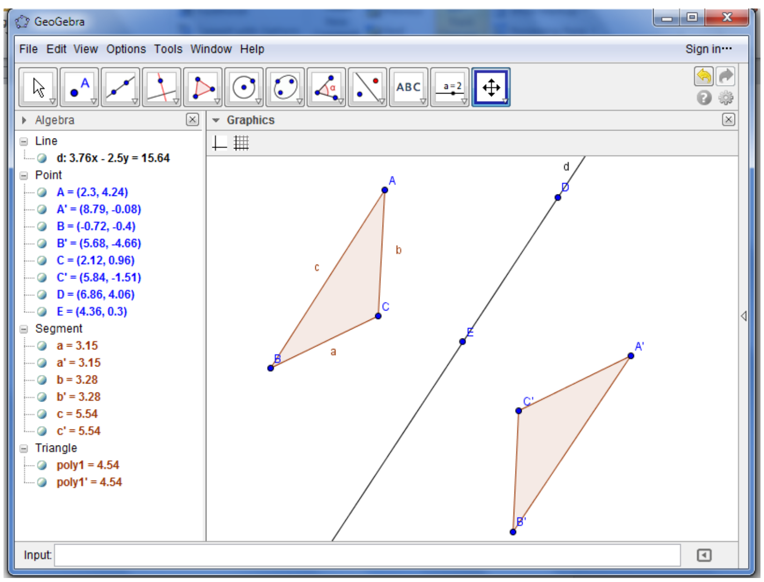


Figure 2. A screenshot of GeoGebra

Table 1. Profile of the participants in this study

Variable	Group	Total (Count)
Sex	Female	88
	Male	102
Teaching grade	Lower secondary (Grade 7 to 9)	70
	Upper secondary (Grade 10 to 12)	64
	Both	56
Workload /week	0 to 10 sessions	29
	11 to 19 sessions	100
	20 sessions and above	57
	missing	4
Teaching experience	0–4 years	69
	5–9 years	57
	10–14 years	33
	14 years and above	31
Age	20–29 years	86
	30–39 years	64
	39 years and above	30
	missing	10
Education level	Bachelor	153
	Master	30
	Others	7
Major in mathematics	Yes	144
	No	46
Computer proficiency	Low	23
	Medium	137
	High	30
DGEs Experience	Yes	143
	No	42
	Missing	5

Table 1 shows the profile of the participants in this study. Approximately 36% of the participants were new teachers (with less than four years of teaching experience) and one third of them have taught Mathematics for more than 10 years. Over 70% of the teachers rated their computer proficiency at a medium level. The majority of teachers (75%) had experienced using DGEs in the classroom.

Measures

For the direct measures of TPB, the original scales by Ajzen (2006) and Francis et al. (2004) were adapted by specifying the type of technology being examined. A sample item was: “In general, I believe the use of DGEs in geometry lesson is convenient.” A standard back-translation procedure was followed, wherein the second author translated the English items into Chinese and back-translated into English by two other researchers who had no knowledge about the scale. The final translated items were included in the reconciled version only after all three researchers had reached a consensus. The final questionnaire contains 11 items that measured behavioural intention, attitudes, subjective norms and perceived behavioural control, on a 7-point Likert scale, with 1= “strongly disagree” to 7 = “strongly agree.” The original English scales have been shown satisfactory validity and reliability in previous studies (Hammer & Vogel, 2013).

For the indirect measures of TPB, the items were elicited from 30 mathematics teachers in Macau who were knowledgeable about and have employed DGEs in their teaching. Their responses to an open-ended questionnaire were coded to generate the indirect measures for each TPB variable. The detailed coding process and results could be referred in Chan (2015). We invited three graduate students to respond to the indirect measures to examine the validity of the measure.

Data analysis

Structural equation modelling (SEM) was employed in this study its ability to analyse the relationships between the latent and observed variables and estimate random errors in the observed variables directly, giving rise to more precise measurements of the items and constructs in the survey. As the focus of the present study is on a modified TPB model, SEM has an added advantage over traditional data analysis techniques by modelling the relationships among latent variables thus aligning with the practice of hypotheses testing (Hoyle, 2011). Using the two-step approach to SEM, we first estimated the measurement model (CFA model) to describe how well the observed indicators (survey items) measure the unobserved constructs. In the second step, we estimated the structural part of the SEM to specify the relationships among the exogenous and endogenous latent variables. The measurement model and structural model were tested with AMOS 7.0 using the maximum likelihood estimation (MLE) (Schumacker & Lomax, 2010). Several goodness-of-fit indices were used to evaluate the structural model: the chi-square test, root mean square error of approximation (RMSEA) and Standardized Root Mean Residual (SRMR), Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) (Kline, 2010). Values of .90 or more for the CFI and TLI, and values of .08 or less for RMSEA and SRMR represent an acceptable fit (Hair, Black, Babin, & Anderson, 2010).

To examine the moderation effects of age, gender, teaching experience, and technology experience on the key relationships in the proposed model, a series of multi-group analyses were performed. We used the median value to divide each moderator into two groups to represent the upper and lower limits, except for DGEs experience, which was divided by “with experience” and “no experience.” The individual parameter estimate of each path in the model was compared for high and low levels of each variable (Zweig & Webster, 2003). We used the Z-score as a critical ratio (Hunter & Schmidt, 1990) when comparing the mean correlations of moderator subgroups.

Results

Descriptive statistics

All 11 items measuring the four constructs in the TPB were examined for their mean, standard deviation, skewness, and kurtosis. The mean scores ranged from 3.01 and 5.16, indicating an overall positive response to the items that were used to measure the constructs in this study. All standard deviations were above 1.00, ranging from 1.04 to 1.42, indicating a narrow spread of scores around the mean. Skewness and kurtosis indices were small and well within the accepted the accepted level of |3| and |10| respectively (Kline, 2010). On the recommendations from Kline (2010), the data in this study were considered to be univariate normal.

Evaluation of the measurement model

On what is considered an adequate sample size for SEM, researchers recommend a sample size of 100 to 150 cases (Kline, 2010). In addition, researchers also refer to the Hoelter’s critical *N*, which refers to the sample size for which one would accept the hypothesis that the proposed research model is correct at the .05 level of significance. The Hoelter’s critical *N* for the model in this study is 136 and, given that the sample size of this study is 190, structural equation modelling is regarded as an appropriate technique for data analysis. As multivariate normality of the observed variables is assumed in the MLE procedure, the data in this study were examined using the Mardia’s normalized multivariate kurtosis value. The Mardia’s coefficient for the data in this study was 44.186, which is lower than the value of 143 computed based on the formula $p(p+2)$ where p equals the number of observed variables in the model (Raykov & Marcoulides, 2008). On this basis, multivariate normality of the data in this study was assumed.

The results of the CFA are shown in Table 2. All parameter estimates were significant at the $p < .01$ level, as indicated by the *t*-value (greater than 1.96). The standardized estimates ranged from .448 to .963, and these were regarded as acceptable (Hair et al., 2010). The internal consistency of all constructs ranges from .64 to .76. Finally, the measurement model has a good model fit ($\chi^2 = 71.321$, $\chi^2/df = 1.981$, TLI = .921, CFI = .948, RMSEA = .072, SRMR = .053). The adequacy of the measurement model indicated that all items were reliable indicators of the hypothesized constructs they were purported to measure.

Table 2. Results for the measurement model

Item	UE	*t*-value*	*SE*	Cronbach Alpha
ATT1	.649	5.614	.448	.70
ATT2	.922	8.672	.719	
ATT3	1.000	---	.832	
SN1	1.603	5.255	.865	.64
SN2	1.000	---	.543	
PBC1	.762	6.379	.539	.76
PBC2	1.000	---	.866	
PBC3	.789	6.853	.583	
INT1	.419	4.835	.421	.75
INT2	.606	5.917	.557	
INT3	1.000	---	.943	

Note. *$p < .01$. UE: Unstandardized Estimate; SE: Standardised Estimate; --- This value was fixed at 1.00 for model identification purposes.

Evaluation of the structural model and hypothesis testing

There was a good fit for the structural model: $\chi^2 = 71.207$; $\chi^2/df = 2.034$; TLI = .916; CFI = .947; RMSEA = .072; SRMR= .053. Overall, three out of five hypotheses in this study were supported by the data. Except for H_1 and H_4, all hypotheses were supported in this study. Two endogenous variables (behavioural intention to use, attitude towards use) were tested in the research model (Figure 1) and the variance explained in ATT was higher than BI with an $R^2 = 0.523$ and $R^2 = 0.195$, respectively. This means that together, SN and PBC accounted for 52.3% of the variance in ATT. On the other hand, ATT, SN, and PBC accounted for only 19.5% of the variance in BI. The summary of the hypotheses testing results is shown in Table 3.

Table 3. Hypothesis testing results

Hypotheses	Path	Path coefficient	*t*-value	Results
H_1	ATT → BI	.130	1.510	Not supported
H_2	SN → BI	.186	2.313	Supported
H_3	PBC → BI	.197	1.994	Supported
H_4	SN → ATT	.213	1.850	Not supported
H_5	PBC → ATT	.584	4.442	Supported

Tests of direct and indirect effects

Table 4 shows the standardized total effects, direct and indirect effects associated with each of the four variables. A coefficient linking one construct to another in the path model (Figure 2) represents the direct effect of a determinant on an endogenous variable. An indirect effect reflects the impact a determinant has on a target variable through one or more other intervening variables in the model. A total effect on a given variable is the sum of the respective direct and indirect effects. The effect sizes with values less than 0.1 were considered small, those with less than 0.3 are medium, and values with 0.5 or more considered large (Cohen, 1988). The most dominant determinant of behavioural intention is perceived behavioural control, with a total effect of 0.427. This is followed by subjective norm and attitude with a total effect of 0.334 and 0.200, respectively.

Table 4. Tests of direct and indirect effects

		Standardized estimate		
Endogenous variable	Determinant	Direct	Indirect	Total
Behavioural intention	Attitude	.200	.000	.200
	Subjective norm	.212	.042	.334
	Perceived behavioural control	.310	.117	.427
Attitude	Subjective norm	.212	.000	.212
	Perceived behavioural control	.585	.000	.585

Moderation analyses

An examination of the differences by gender revealed that that male teachers expressed more negative relationships in their attitudes towards DGEs and the intention to use technology (*ß* = -.34, Table 5). An opposite pattern was observed in female teachers whose attitudes towards DGEs had a positive impact on their intention to use technology (*ß* =.34). Teaching experience also moderated this path with a similar pattern: teachers who have taught over 10 years tended to report a negative relationship between attitudes and intention to use technology (*ß* = -.97) whereas teachers who have taught for less than 10 years showed a positive attitude towards using technology (*ß* = .20). Further, the path between PBC and attitudes was moderated by teaching and technology experience. Specifically, teachers with more experience in teaching or with using DGEs reported a stronger path (*ß* = .82; *ß* = .57, respectively) than those with less experience in teaching or with using DGEs (*ß* = .22, *ß* = .28, respectively). No moderating effects were observed for age.

Table 5. Results of moderation analyses

Path	Moderator: Gender		Critical ratio
	Male	Female	
ATT → BI	-.34	.34	-2.008**
	Moderator: Teaching Experience		
	More Experience	Less Experience	
PBC → ATT	.82**	.22	-2.618***
ATT → BI	-.97	.20	1.795*
	Moderator: Technology Experience		
	With Experience	No Experience	
PBC → ATT	.57***	.28	-1.828*

Note. ***$p < .001$; **$p < 0.01$; *$p < 0.05$.

Discussion

Straesser (2002) noted that DGEs may be one of the highly-featured software within mathematics education research due to its wide use in schools around the globe. However, past research had mainly focused on the effectiveness of DGEs in improving student's performance (e.g., Dogan & İçel, 2011). The current study explored the determining factors that affect teachers' decision to adopt DGEs in classroom. Consistent with past findings (Cheon, Lee, Crooks, & Song, 2012; Stols & Kriek, 2011), perceived behavioural control was found to be the most powerful factor in explaining Macau teachers' intention for using DGEs.

From development, DGEs were developed for users to explore mathematics concepts with its interactive diagrammatic interface (Laborde, 2007) and this feature poses a heavy demand on teachers' classroom activity design (Jones, 2002). To use DGEs effectively, teachers need to possess a sufficient level of domain knowledge, conceptions of mathematics learning as well as pedagogical strategies (Koehler & Mishra, 2009). Thus, what teachers' believe about their knowledge and skills to use this software are important factors in their decision to use DGEs.

Next, subjective norm was a significant variable in explaining Macau teachers' intention to use the DGEs. Consistent with current research, it appeared that the teachers in this study had regarded their subject leaders, school principals, and colleagues as important influences to their use of DGEs in the Macau classroom (Teo & Zhou, 2014; Lee, Ceereto, & Lee, 2010). In the Macau context, decisions on technology procurement and adoption are largely made by the school leaders. There is limited autonomy on the part of the teachers on technology integration hence the big impact of their normative beliefs on their behavioural intention to use the technology.

The missing support for the positive effect of attitudes on teachers' intention to continue using DGEs in teaching mathematics (H_1) was unexpected as attitude towards technology has been documented to be a strongest predictor of intention to use technology (e.g., Cheon et al., 2012; Stols & Kriek, 2011). Although the majority of the teachers in this study had used DGEs, they had not received any formal training in using it. Consequently, they may not have optimised the use of DGEs to guide students' learning and were unaware of various innovative and pedagogical uses of DGS in the mathematic classroom- experiences that may have shaped teachers' attitude. Coffland and Strickland

(2004) noted that teachers' attitudes and technology awareness were positively related and those who were trained in the integration of technology were more likely to develop positive attitudes towards using technology for teaching. To an extent, the interaction between knowledge and experience in DGEs of the participating teachers in this study might have weakened the predictive power of attitudes on technology use intention.

Also noteworthy was that perceived behavioural control had a significant influence on teachers' attitudes (H_5), despite the missing direct effect of attitudes on intention. This was in conflict with studies where attitudes had mediated the relationship between perceived behavioural control and intention (e.g., Yang & Zhou, 2011). However, considering that perceived behavioural control is jointly dependent on motivation (intention) and ability (behaviour control) (Ajzen, 1991), the motivation dimension seemed to be more closely relevant, when linked with other variables such as attitudes, explaining the significant influence from PBC to attitudes.

As an external variable, subjective norm did not have a significant effect on attitudes. Although some researchers have argued that the expectations from the important "others" had an impact on their attitudes toward technology use (Teo, 2009), which in turn influenced the intended use of that technology, our data showed that this was not the case. In places where key decisions are made collectively, as in the case of Macau, individual preferences may not have much influence on the outcomes, such as the type of technology to use for instruction. This may be the sentiments of the Macau teachers in our study who felt it more important to comply with policies or decisions made by their school leaders, rather than acting from their personal views, explaining the significant influence subjective norm had on intention, but not on attitude towards the use of DGEs.

Although there was evidence in support of a positive relationship between each demographic variable and the intention to use technology, the findings in this study revealed only a few to be statistically significant. One possible reason is that this study had focused on teachers' individual background in the selection of moderators and, while these could have had an impact on teacher's attitudes and their technology intention, or between PBC and attitudes, it may be possible that other variables related to a teacher's perceptions had greater influences in other paths in the model, such as self-efficacy (Islam, Khan, Ramayah & Hossain, 2011) or voluntariness (Venkatesh et al., 2003). Future studies are warranted for further investigation.

Implication for theory and practice

There are few studies which reveal teachers' intention of using special mathematical software. This study provides empirical evidence to support the argument that the role of three direct variables of TPB model as predictors of intention of using DGEs is different with that of general software such as PowerPoint (Lee et al., 2010). This study verifies the importance of specifying precise behaviour when applying TPB, and contributes to a greater understanding of the validity of the TPB as a model to explain the intention to use technology for teaching mathematics with a sample of Asian teachers, in particular, among Macau teachers. Both teachers' beliefs that they have sufficient knowledge and skills to use the technology tool as well as their subject leaders, school principals, and colleagues' recommendations emerge as important factors to their use of technology.

Findings of this study suggest that decision makers in schools can continue playing a role in promoting the use of DGEs. Technology integration in the Macau education system is not as clear as those in other countries such as Australia and the United Kingdom. Therefore, creating a vision of using technology to facilitate teaching and learning of mathematics could increase teachers' intention of using such technology. Nirode (2012) noted that teachers' use of DGEs was restricted to convergent tasks of basic construction and measurements. School leaders should create conducive environments to support mathematics teachers' adoption of DGEs in the classroom by providing time and access to resources for teachers to explore various technologies and ways to use them, such as properly installing software in school computers, organizing workshops and seminars, promoting peer sharing of lesson plans to allow for the production of dynamic lessons and discussions of related pedagogical issues and so forth. These measures could enhance teachers' perceived behaviour control which in turn strengthens their attitudes towards DGEs.

Limitations

Several limitations exist in this study. First, the participants in this study were recruited from the secondary schools. Hence, replication studies are needed in order to generalize the results of this study to all in-service teachers. In addition, future research should endeavour to understand students' perceptions since they are key stakeholders in education. Finally, since a web-based questionnaire is used in this study, a bias towards low computer anxiety and high computer self-efficacy could be present in the data thus skewing the respondents' inclinations of adopting technology (Svendsen, Johnsen, Almås-Sørensen, & Vittersø, 2013). Finally, future research could include a qualitative study to cross-validate the proposed model in this study.

Conclusion

This study aimed to examine Macau teachers' intention of using DGEs in mathematics classroom using the theory of planned behaviour. Results showed that Macau teachers were affected by their important others and the perceived behavioural control. Evidence of this study confirmed that the predictive power of direct determinants of intention would be different in different technology.

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