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Salient Beliefs of Secondary School Mathematics Teachers Using Dynamic Geometry Software

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Even though dynamic geometry software (DGS) is becoming an emergent instructional tool for mathematics teachers, many teachers are still in the process of consideration about whether to use it. In order to encourage teachers to use DGS, this study seeks to discover mathematics teachers' salient beliefs about the use of DGS in mathematics class. The theory of planned behaviour serves as the theoretical framework for understanding teachers' intentions to use DGS. Thirty mathematics teachers who have knowledge of and experience using DGS were invited to fill out an online survey. Content analysis of teachers' responses was analysed using the theory of planned behaviour. The behavioural, normative and control beliefs of mathematics teachers using DGS in class were identified. These noticeable beliefs of teachers may be used to create conditions for teachers to successfully integrate this new tool in mathematics class.

Keywords: In-service secondary school mathematics teacher; beliefs; dynamic geometry software.

INTRODUCTION

Dynamic geometry software (DGS) is becoming an emergent instructional tool for mathematics teachers because of its potential to enhance the teaching and learning of mathematics (Ellington, 2003). DGS is considered as a cognitive technological tool in mathematics education (Zbiek, Heid, Blume, & Dick, 2007) because it enables users to manipulate mathematical objects and relations in an intuitive way. In term of instruction, teachers may use DGS to represent and explain mathematical concepts and relations much more easily and more productively than the traditional pencil and paper environment (Laborde, 2007; Pierce, Stacey, Wander, & Ball, 2011). It also facilitates students' inquiry of mathematical concepts through its graphical and algebraic interface (Straesser, 2002). Studies have found that the appropriate use of DGS has a positive impact on student achievement (Hollebrands, 2007) and motivation and engagement (Sinclair, 2006).

Despite its potential in mathematics education, the adoption of DGS in mathematics classrooms is not widespread in many educational systems (Wong, 2003). Research on technology integration offers some explanations for this phenomenon. These include teachers' knowledge and attitudes towards technology, access to technology, support given to teachers, and school settings (Artigue, 2002; Fuglestad, Healy, Kynigos, & Monaghan, 2011; Inan & Lowther, 2010). Much of the prior work on the integration of technology into mathematics classrooms was mainly on devices such as graphic calculators, computer applications in general or new devices such as laptops. Although these studies offered insights on conditions of technology integration, there is a dearth of research on the beliefs of mathematics teachers who use cognitive technological tools, in particular DGS. Therefore the aim of this study is to identify the salient beliefs of secondary school teachers about the use of DGS so as to generate conditions for their adoption of DGS.

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State of the literature

- The study aims to develop a scale instrument to allow us to determine the self-efficacy perceptions of secondary education teachers regarding their use of technology when educating students.
- The developed scale instrument was obtained in the wake of the data gathered from secondary education teachers.
- According to the conducted analyses of the developed scale instrument, it was determined to have validity and reliability.

Contribution of this paper to the literature

- The developed scale instrument is going to contribute to the literature in that it will make the information technologies coherent with the education, thus creating a model for teachers developing and designing the learning environment.
- That the developed scale instrument on information technologies included numerous expressions about different aspects is vital in terms of it being intended for the use of all education instruments.
- It is thought that the scale instrument puts forth the self-efficacy perceptions regarding the use of information technologies from the point of view of basic skills and the anxiety state.

Mathematics teachers' beliefs in the process of technology integration

As teachers are the central stakeholders in the mathematics classroom, teachers' pedagogical and personal belief were vital in the quest for technology integration (Ertmer 2005). In fact, Ertmer's argument was supported by empirical study (Inan & Lowther, 2010). Many teachers view technology as being quite important in a mathematics classroom (Lin, 2008). Adopting new technology in classroom practices is far more complex than expected (Artigue, 2002). The adoption of DGS in mathematics education demands that teachers have technical knowledge about how to use DGS and the conceptual understanding of mathematics. Teachers are faced with a series of new challenges (Anthony & Clark, 2011; Laborde, 2008). These include determining the role of technology in mathematics instruction, using technology in a misaligned environment, learning and mastering new knowledge and skills within the limited professional development opportunities in schools, pedagogical issues, tackling new classroom management issues, and adapting teaching style to the new forms of interaction. Encountering such new cultural practices, it is not an easy decision for teachers to include DGS in the classroom (Fuglestad, et al., 2011).
For those who adopted DGS in class, teachers were inclined to limit the exploration tasks of students in order to keep the locus of the classroom control (Ruthven, Hennessy, & Deaney, 2008). Teachers usually consider DGS as an instructional tool to supplement their instruction (Clements, Sarama, Yelland, & Glass, 2008). In fact, the intuitive and interactive aspect of DGS supports the discovery approach of learning where students might manipulate mathematical objects within it (Laborde, 2007).

Since teacher beliefs are influential predictors of their behaviour (Kagan, 1992; Pajares, 1992), examination of teachers' beliefs about the role of DGS in mathematics classrooms is necessary. It may predict teachers' decisions and classroom practices regarding the employment of DGS or not (Hermans, Tondeur, van Braak, & Valcke, 2008). For instance, Geiger (2011) found that teachers' dispositions about the use of a computer algebra system was influenced by their personal view of the use of technology and their perception of mathematical modelling. Research studying teachers' beliefs about the use of mathematical cognitive tools in mathematics education is missing (Bretscher, 2008). Only one study has attempted to examine teachers' beliefs and intentions about the use of DGS(Stols & Kriek, 2011).

Stols and Kriek (2011) conducted an exploratory study using a questionnaire to understand 22 mathematic teachers' beliefs and intention of using DGS. Items in the questionnaire were developed based on existing literature of technology adoption. They found that about the perceived usefulness of DGS and beliefs about teachers' level of technological proficiency were the two critical predictors of teachers' use of technology. Findings of Stols and Kriek (2011) contribute to our understanding of teachers' beliefs using DGS. Salient beliefs of teachers include the pedagogical compatibility of the technology, perceived ease of use of the technology, and its usefulness. Teachers are affected by their colleagues, students, principals and parents. Access to technology, technical support by a technology officer and their own technological capability are their concerns as well. Although the authors mentioned that the salient beliefs of teachers presented in the questionnaire were developed based on the existing literature, it is arguable whether parents and students are sources of social pressure on teachers. This is because many parents are not aware of mathematical tools such as computer algebra systems or DGS. They are unlikely to give any recommendation or comments to teachers. In addition, it is not clear how these salient beliefs are identified.

Since participants' responses are collected right after their professional development workshop, this implies that their beliefs are only tentatively affected by the learning experience in the workshop. The findings of Stols and Kriek (2011) are biased and might not be representative of actual classroom settings. Practical dilemmas encountered by mathematics teachers should be considered. Therefore, this paper fills the gap by inviting mathematics teachers who have knowledge of DGS and actual experience of using DGS in the classroom to divulge their beliefs about the use of such technology through the theoretical lens of the theory of planned behaviour.

Theoretical framework – TPB

This study applies Ajzen's (1985) Theory of Planned Behaviour (TPB) as the theoretical framework listed in Figure 1 to understand mathematics teachers' salient beliefs about the use of DGS. TPB is a mature theory that has undergone rigorous validation processes (Icek Ajzen, 2011). It has been widely used to predict human social behaviour in different settings, such as smoking (Hassandra et al., 2011), self-examination of breast and skin protection behaviours (Matterne, Diepgen, & Weisshaar, 2011), and sleep hygiene behaviour (Kor & Mullana, 2011). It is also being applied in education to explain teachers' intentions to use technology in the classroom, for example using Web 2.0 technologies in K-12 classrooms (Sadaf, Timothy J. Newby, & Ertmer, 2012), using presentation software such as PowerPoint to create and deliver lessons (Lee, Cerreto, & Lee, 2010), and using DGS in class (Stols & Kriek, 2011).

TPB is an extension of the Theory of Reasoned Action (TRA). It assumes one's decision making process about how to behave in new situations depends on three major variables, namely attitude towards the behaviour, subjective norm, and perceived behavioural control. These variables are the direct determinants of the strength of one's intention to carry out a behaviour. They are driven by a set of related beliefs, namely behavioural belief, normative belief, and control belief. These beliefs are the indirect determinants of the intention. This theory assumes that the intention is based on one's rational judgment of these three direct variables. However, the beliefs that one possesses might be irrational or biased. They might be inaccurate or based on incomplete information. This theory enables us to examine teachers' underlying beliefs about the use of DGS in classroom. The main constructs of the theory are presented as follows:

Attitude towards the behaviour is a person's self-evaluation of a particular behaviour based on a set of **behavioural beliefs** linking the behaviour to its probable outcomes. These beliefs might be both positive and negative. In the case of this study, teachers' intentions to use DGS in mathematics class depends on their personal positive or negative beliefs regarding the use of DGS in producing favourable outcomes. Positive beliefs tend to strengthen teachers' intention of having the behaviour while negative ones are likely to weaken their will to have the behaviour.

The second variable, **subjective norm**, is a person's evaluation of the social pressure of a particular behaviour. It is affected by a set of **normative beliefs** which refer to "the likelihood that important referent individuals or groups approve or disapprove of performing a given behaviour" (I. Ajzen, 1991 p.195). Normative beliefs are the source of social pressure. Normative sources affecting teachers' behaviour include their colleagues, school leaders, students, parents and teacher educators. If the other important stakeholders support the behaviour, teachers are more likely to have this behaviour and vice versa.

The third variable, **perceived behavioural control**, is one's perception of the ease or difficulty of performing the behaviour (I. Ajzen, 1991). It is determined by the total set of accessible **control beliefs** about the presence of factors that may facilitate or impede the realisation of a behaviour. Factors may be internal and external. With the integration of DGS in mathematics class, they are concerned with a set of accessible requisite resources or opportunities available for teachers. Internal factors include teachers' beliefs of fluency in using DGS and beliefs of capability in managing technology-based classes. External environmental factors are beliefs about the availability of computing resources and supporting services.

Purpose of the study

The main purpose of the current study was to elicit in-service mathematics teachers' salient behavioural, normative and control beliefs related to their use of DGS in the classroom. To understand these beliefs, mathematics teachers' current practices using DGS was examined. The specific research questions of the study are as listed below:

- *What do teachers assign the role of DGS in mathematics education?*
- *What are mathematics teachers' behavioural, normative and control beliefs about the use of DGS?*

METHODOLOGY

Research Design – This formative study aimed to elicit mathematics teachers' views on the use of DGS. In order to have beliefs on the value of DGS in teaching and learning, teachers had to be aware of the features and limitation of DGS. Experience of using DGS was also an advantage. Therefore, a purposive sampling

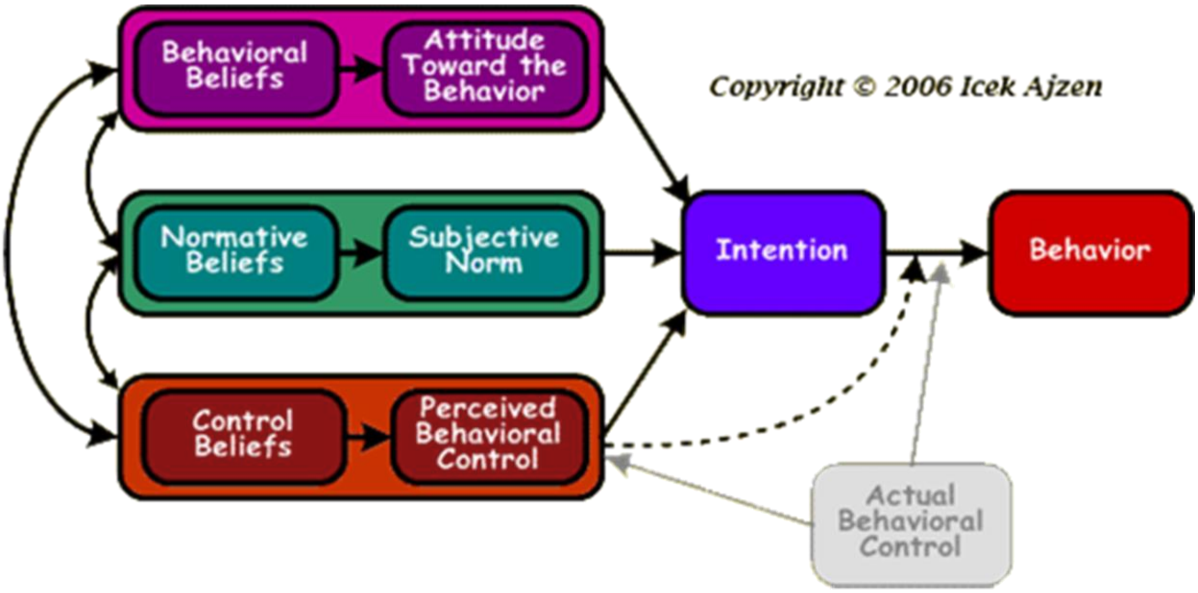

Figure 1. The theory of planned behavior

method was used to select participants for the online survey. Criteria for selection include knowledge of DGS, experience of teaching in secondary education and teachers representing various computing ability. The specific aim was to explore and locate teachers' beliefs about DGS in the classroom. The study was therefore based on an exploratory qualitative research design and used an online survey to collect data.

***Setting* –** This study was done in Macau, a special administration region of China where over 90% of schools are private with a small proportion of public schools. This implies that the mathematics curriculum in Macau varies substantially. Teachers may adopt textbooks which are from mainland China, Hong Kong or the UK to design instruction for students. The role of technology in mathematics education can hardly be located in any official document of local education department. Despite this, there are schools in Macau which encourage teachers to use technology in the classroom.

***Participants* –** A total of 30 in-service mathematics teachers participated anonymously in the online survey in April 2012. They were provided with written information about the nature and purpose of the study. They could withdraw their input at any time without any penalty. Participants were mainly from a training course on the use of DGS in July 2011, a mathematics course in a teacher education programme in 2010, and a school partnership programme promoting the use of DGS in 2010. These teachers had at least 15 hours of basic training on using DGS in mathematics classes. They were mainly teachers in private schools teaching secondary mathematics with only one from a public school. Table 1 showed the general demographic information of participants. There were 18 (60%) males and 12 (40%) females. Among these, 11 (37%) were in the 25–29 age group, 7 (23%) were in the 30–34 age group, 8 (27%) were in the 35–39 age group, and 4 (13%) were in the 40–49 age group. The average teacher age was 31. These teachers included both new teachers and highly experienced teachers. The number of teachers with less than 4 years of experience was 6 (20%). Ten (33%) of them had 5 to 9 years in-school teaching experience. Nine of them had 10–14 years' experience, while 5 of them had more than 15 years of teaching experience. Their average teaching experience was 8 years. Participants in the current study were less experienced than those in the study of Stols and Friek (2011). In terms of computing capability, the number of teachers with a low, medium and high level of proficiency were 1 (3%), 23 (77%), and 6 (20%), respectively. The majority of the teachers rated themselves as comfortable users of computers.

***Data collection* –** Participants were requested to fill out an online survey which was divided into two sections. The first section consisted of eight multiple choice items to determine the general demographics of the participant and their current practice of using DGS in classroom. These items were mainly in selected response formats. For the role of DGS in mathematics classes, the options available for teachers to choose from include 1. An instructional tool (Clements, et al., 2008), 2. A learning tool (Laborde, 2007) and 3. An assessment tool (Nicol & Milligan, 2006). The second session had nine open-ended questions, based on the TPB variables, to examine teachers' behavioural, normative and control beliefs associated with the use of DGS in classroom (I. Ajzen, 2006). Teachers were

Table 1. General demographic information of participants

Category		Number (Percentage)
Gender	Male	18 (60%)
	Female	12 (40%)
Age		
	25–29	11 (37%)
	30–34	7 (23%)
	35–39	8 (27%)
	40–44	3 (10%)
	45–49	1(3%)
Teaching Experience		
	0–4	6 (20%)
	5–9	10 (33%)
	10–14	9 (30%)
	15–19	5 (17%)
Computing Proficiency Level		
	Low	1 (3%)
	Middle	23 (77%)
	High	6 (20%)

requested to type in their opinions. Sample questions included in the survey were listed below:

- *What do you believe the advantages of using DGS in the classroom are?*
- *What do you believe the problems of using DGS in the classroom are?*
- *Are there any individual or groups who would disapprove of your integration of DGS in the classroom?*
- *What factors or circumstances would enable you to use DGS in the classroom?*

Data analysis **–** Teachers' responses to the open-ended questions were classified by two independent researchers. The collected data were analysed using the quantitative content analysis approach in the categories of behavioural, normative and control beliefs in the TPB model (Miles & Huberman, 1994). Their frequencies were counted in order to identify which subtheme had the greatest explanatory potential. In order to ensure the validity and reliability of the study, data were coded again using the salient beliefs located in the literature (Lee, et al., 2010; Stols & Kriek, 2011).

RESULTS

Mathematics Teachers' practice of using DGS

Before presenting the salient beliefs of teachers using DGS in mathematics class, the way that teachers use DGS in mathematical activity was shown first so as to facilitate the interpretation of themes identified in the open-ended survey questions. Table 2 listed the kind of DGS that mathematics teachers in Macau used in class. Geometer's Sketchpad was the most widely used among teachers in Macau. It was, perhaps, the first tool introduced to teachers in Macau. The other popular DGS tools included Z+Z, SG-Lab/PG-Lab and Geogebra. Tools such as Z+Z and SG-Lab/PG-Lab were developed by Chinese scholars to meet the needs of teachers in Chinese classroom contexts. Geogebra was a more recent tool available for teachers to use. Due to its user-friendliness and availability in a free and multilingual interface, there was some proportion of teachers using it. Since teachers had knowledge of DGS, the majority of teachers used DGS in their class and 17% of the participants did not use DGS in class. The beliefs of teachers presented next may shed light on this phenomenon.

The frequency of teachers using DGS with respect to the topics in the mathematics curriculum was listed in Table 3. In fact, three teachers (10% of the participants) used DGS in nearly all mathematics topics. Fourteen teachers (47% of them) used DGS in some of the mathematics topics. There were also a large proportion of teachers (43%) who only used DGS in one or two topics. This implies that most of the teachers do use DGS in class, but not extensively.

The majority of the teachers used DGS in classrooms where there was only one computer to project information to students. This finding echoes with the following result that teachers mainly used DGS as an instructional tool. A small proportion, 10%, of teachers used DGS in a computer laboratory where students had the opportunity to manipulate dynamic figures through interacting with DGS.

The majority of teachers used DGS as an instructional tool. They usually presented dynamic figures to facilitate students' visualisation of geometrical concepts and relations. Only one teacher created a learning environment where students explored mathematical problems with DGS. This resonates with

Table 2. Specific DGS used by mathematics teachers

Dynamic Geometry Software	No. of Teacher (Percentage)
Geometer's Sketchpad	20 (67%)
Z+Z	6 (20%)
GeoGebra	6 (20%)
SG-Lab/PG-Lab	8 (27%)
Others	3 (10%)
Do not use any DGS	5 (17%)

Table 3. Teachers using DGS: frequency, location and functions

Using DGS in mathematics topics	Number of Teacher (Percentage)
All the mathematics topics	2 (7%)
Most of the topics	1 (3%)
Some of the topics	14 (47%)
One or two topics	13 (43%)
Classroom	27 (90%)
Computer laboratory	3 (10%)
Instructional tool	26 (87%)
Learning tool	1 (3%)
Assessment tool	2 (6%)

the findings that a small number of teachers used DGS in computer rooms. Two teachers allowed students to use DGS as part of the assessment process.

Salient beliefs of teachers using DGS

The TPB model assumes that a behavioural intention is associated with behavioural beliefs, normative beliefs and control beliefs. These fundamental beliefs provide important information about a given behaviour. The content analysis and frequency counts of teachers' responses in the open-ended questions are listed in Table 4.

Behavioural beliefs

Behavioural beliefs are beliefs about the probable outcomes of using DGS in class and the corresponding judgments about these outcomes. Teachers' responses to the questions of the advantages and problems of using DGS in class are analysed. Three themes emerge out of teachers' responses, namely teachers' instructional process, the engagement of students in the instruction, and students' learning. They are mainly related to the perceived usefulness of DGS detailed in Stol and Friek (2011).

Firstly, using DGS in class affects **teachers' instructional process** both positively and negatively. Positively, teachers reported that DGS enabled them to draw accurate and clear diagrams faster. Time spent drawing geometric diagrams was saved for other purposes. Having such diagrams enhanced their instruction, as it made the abstract mathematical concepts became more concrete. Teachers also expressed that the instructional process became more interesting with the availability of dynamic diagrams. On the other hand, teachers reported that it was time-consuming to prepare dynamic diagrams and editing diagrams during instruction could not be easily done. In addition, they believed that students did not know how to operate DGS and this limited their instruction to demonstration of dynamic figures to students.

Engagement of students in instruction is another issue that teachers mentioned in the survey. Teachers said that students' attention in class was better with the use of DGS (Lee, et al., 2010). Students were attracted by the dynamic and concrete features of concepts presented through DGS. Teachers also suggested that presenting mathematical concepts through DGS should not be a long-term strategy. This is because students lost attention quickly when they were only passively watching and listening to teachers' explanations. They pointed out that if students were able to interact with DGS, their engagement in class would be more sustainable.

The third theme of teachers' behavioural belief is that DGS is conductive to students' learning in both cognitive and affective domain. In cognitive aspects, the following response given by one teacher was quite representative. "DGS enables students to understand the relationship between the changes in value with respect to geometric properties. In addition, students learn the structure of geometric figures and their position better." Teachers believed that DGS would facilitate students' understanding of graph functions, locus formation and spatial properties. The dynamic changes of diagrams with respect to their various inputs helped students to visualise abstract concepts and make associations between different representations. It clarified students' doubts and increased their interest.

Table 4. Major themes and frequencies of teachers' behavioural, normative and control beliefs

Survey Themes / Categories	**Frequency (n=30)**	**Frequency (n=30)**
Behavioural beliefs: outcome of using DGS in class	Positive belief	Negative Belief
Teacher's Instructional Process	18	16
Students' Learning	10	5
Students' Engagement in Instruction	6	10
Normative beliefs: People Who Expect the Use of DGS		
Expectation of School, Subject Leaders	25	-
Professional Development Organisation	5	-
Control Beliefs: Internal and External Enablers/Constraints		
Supporting Equipment or Software	8	9
Teaching Load	3	7
Teaching Materials	4	3
Professional Development Opportunities	3	2
Examination	1	-
Self-efficacy in DGS Use	-	6

Teachers considered that if students were given such dynamic instruction, both their interest and performance in achievement tests might improve. Concerns raised by teachers included: (1) to ensure students' understanding of the mathematical idea presented in the DGS environment and (2) students relied on DGS to construct dynamic figures. They worried that if students constructed geometric figures, they might not have the know-how of the construction process. They were concerned that the heavy use of DGS might induce students to rely on the software and not to use their brain to think and solve problems. Indeed, this belief reflects their incomplete understanding of DGS. In summary, teachers supported the use of DGS in classroom.

Normative beliefs – Among the sources of social pressure, mathematics teachers revealed that the expectation of schools was the most important one. They used the term "school" to mean school principal, subject leader and colleagues. Some also pointed out that professional organisations, such as the Faculty of Education and Macau Mathematic Education Association, might affect their intention to employ DGS in class. Responses did not reveal anyone who disapproved of the behaviour of using DGS except teachers themselves. This is understandable, as using DGS in class requires teachers to change their normal practice. Interesting results are identified when compared to the findings of Stol and Friek (2011).

Control beliefs – Referring to Table 4, having sufficient equipment and software in class was the main factor that mathematics teachers requested. Teachers indicated that a lack of computing resources was the problem. DGS was not installed on the computer in every classroom. Teachers' responses indicated the problem of the integrity of computing resources in schools. Time was another issue that many teachers raised. Teachers reported that their workload was too heavy at the time. If there was a reduction in their workload, they would have more time to prepare teaching materials. This was related to the request of having textbooks which integrated DGS into the teaching and learning activities. The following response illustrates the practical consideration of teachers in their use of DGS (Anthony & Clark, 2011).

"I would like to use DGS if the instructional equipment in my school is sufficient. There are adequate teaching resources. Projection of the visualisation does not affect my writing on the whiteboard. The topic to be covered is better illustrated using DGS and I have the time to prepare it."

In addition, many teachers wrote that they had problems in mastering the skills of DGS operation and the pedagogy of teaching mathematics with DGS. This finding might be the source of the negative attitudes located in the behavioural beliefs section. It verified the findings presented in previous section, as well. Teachers said that even though DGS was easy to learn, it was difficult to master. Since teachers were not familiar with DGS, they needed more time to prepare for dynamic resources. Therefore they pointed out the need to have support in terms of online discussion, DGS resources, experience sharing opportunities and technical support. The permission to use DGS in examination was another concern that teachers raised. Teachers were suspicious of whether students' mathematics achievement would be better when they taught with DGS. This is because the existing assessment practice did not allow students to use DGS during examination.

DISCUSSION

The purpose of the study is to understand the behavioural, normative and control beliefs of mathematics teachers using DGS in class. Results showed that mathematics teachers had both positive and negative beliefs on the outcomes of using DGS in mathematics classes. Their intention to use DGS in mathematics class is related to improving the quality of teaching, sustaining students' engagement in class and enhancing students' mathematics achievement. Part of the results is similar to the existing literature (Lee, et al., 2010; Stols & Kriek, 2011). That is, the adoption of DGS by teachers is mainly related to their belief that DGS might enhance their instruction and facilitate students' learning. Both the positive and negative beliefs demonstrated by teachers indicate that DGS enhanced their instruction. They believed that DGS is able to represent the mathematical properties of a mathematical object (Zbiek, et al., 2007). That is, some of the existing problems are solved. However, it also generates new pedagogical challenges for them. Teachers think that students should be given the opportunity to use a dynamic environment in order to keep their attention in class. In the study of Lee et al. (2010), they found that teachers' positive attitudes towards PowerPoint outweigh its negative ones. However, this is not the case in the current study. Unfamiliarity with DGS might be one reason for the differences.

Normative belief refers to the significant personnel who support or disapprove of teachers' use of DGS in class. Teachers' responses revealed that no one disapproved of their usage of DGS except themselves. For those who support the use of DGS in class, the school where they were teaching played an important role. Teachers reported that they were influenced by their colleagues and subject leaders. Some teachers also reported the role of professional associations and the teacher education in shaping the use of DGS. The current finding contrasts with the existing literature, where the sources of normative beliefs are both students and parents (Lee, et al., 2010; Stols & Kriek, 2011). This might be due to the specific nature of DGS. DGS is not a general program such as PowerPoint. As a cognitive technological tool in mathematics education, professional organisations in Macau endorsed its value and organised professional training opportunities for teachers. This in turn might encourage teachers to try out the tool. On the other hand, parents and students might not be aware of the functions or usage of the software, so they are not the main source of social pressure on teachers. As shown in the result section, teachers believed that students did not know how to operate DGS and the location where the majority of teachers used DGS was in classroom. This implies that students have little opportunity to use DGS. They are only passively watching teacher's presentation and demonstration (Ruthven, et al., 2008). Therefore, the main source of social pressure on teachers is from the school authority, such as the principal or subject leaders.

The results in this study revealed that time for creating DGS-based materials, training and support of DGS operation and pedagogy, and the equipment and software available in class were teachers' concern. These control beliefs are similar to the findings of existing research (Gialamas & Nikolopoulou, 2010; Lee, et al., 2010; Stols & Kriek, 2011). Teachers considered that the reduction of teaching load and the provision of sufficient equipment in class might positively influence their intention. They also pointed to the need to master their skills in creating DGS materials through online peer exchange activities. In addition, teachers indicated the importance of having DGS-based teaching materials in publications and the inclusion of DGS in examination. In Macau, teachers usually follow a textbook to design and plan instruction. If there are no DGS-based teaching resources, it might hinder teacher's use of DGS in class. This finding is distinctive, as it points to the fact that teachers rely on textbooks in their daily teaching activities (Weiss, Banilower, McMahon, & Smith, 2001). They use them as a primary source to sequence teaching materials. They also provides teachers with ideas about how to engage students with activities, as they contain a rich resource of sample problems, diagrams, examples and homework assignments (Reys, Reys, & Chaves, 2004). Given the prominent role of mathematics textbooks, teachers' call for materials supporting DGS-based instruction is crucial to their intention to use DGS.

Another external factor affecting teachers is whether students are allowed to use DGS in examination. Since DGS tools are not allowed in examination at the moment, this seems to exert a negative influence on their intention to use DGS in the classroom. Teachers doubted whether the use of DGS would increase students' score in pencil and paper-based examinations. This finding is supported by the fact that teachers' classroom practice is often affected by school-based summative assessment and public examination (Morrison & Tang, 2002).

CONCLUSION

The results of this formative study were the salient beliefs of in-service mathematics teachers about the use of DGS in mathematics classrooms. Their behavioural beliefs suggested that teachers had both positive and negative beliefs about the use of DGS in the classroom. The integration of DGS into the classroom solved some of the existing instructional problems faced by teachers, however it also generated new problems which teachers had to address, such as students learning how to use DGS and time to prepare DGS-based materials. The normative beliefs of teachers showed the importance of school leaders, subject leaders and professional organisations. To facilitate the integration of DGS in the classroom, both school leaders and professional organisations might consider seeking collaborative projects to support teachers' innovative teaching with DGS. Through such experience, teachers are more likely to change their existing practice. Online professional development opportunities for teachers to reflect on and exchange ideas with their colleagues might be another way to refine teachers' beliefs.

In terms of internal and external factors, teachers' beliefs showed that sufficient conditions for the integration of DGS in mathematics classes were still lacking. These included time for the creation of DGS materials, training opportunities for the operation of DGS, sufficient hardware and software, DGS-based textbooks and the inclusion of DGS in examinations. Some of the obstacles, such as the issue of using DGS in examinations, cannot be solved within a short period of time. In the Programme for International Student Assessment (PISA) 2015 cycle, computer-based assessment will be the primary mode of testing (OECD, 2013). An onscreen scientific calculator will be provided to the students. This fact will trigger education departments to consider the possibility of having DGS in summative assessment. Some beliefs expressed by teachers may be solved quite easily. For instance, one easy and quick manageable task was to set up DGS on the classroom computer. This might encourage teachers to use DGS in class.

The contribution of this paper to the existing literature is the identification of the salient beliefs of in-service mathematics teachers who have experience using DGS. Teachers have both positive and negative attitudes towards the use of DGS. This paper supports the claim that social sources, such as school leaders and professional organisations, influence teachers' adoption of cognitive technological tools, DGS. In addition to the existing literature, this paper finds that teachers are affected by the availability of DGS-based textbooks and the possibility of using DGS in tests. These salient beliefs of mathematics teachers identified in the current study are far more complex than those located in the prior literature. These information should be taken into consideration by school principals when when they are planning and devising favourable conditions for teachers to integrate DGS in mathematics class. In addition, this information is important for the construction of an instrument using TPB (I. Ajzen, 2006). Then the instrument can be used for data collection from a large sample size.

Limitations and further research

Firstly, the data from this study were collected through online self-reports of secondary mathematics teachers. As there is no interviewer to probe into participants' view, collected data might not be detailed. Therefore, future studies could use a mixed method approach to verify the existing findings through both questionnaire and interviews with a larger sample. Secondly, attempts could be made to compare the beliefs of both in-service and pre-service mathematics teachers. As more pre-service teachers were given training on the use of DGS and pedagogy in a technology-based environment, it is necessary to study pre-service teachers' beliefs about the use of DGS in the classroom, too. Results might enable teacher educators to devise strategies to strengthen the intention to use DGS at the teacher-training stage. If there are different beliefs between in-service and pre-service teachers, school leaders might adjust school policy to suit new teachers.

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