

Understanding Malaysian Pre-Service Teachers Mathematical Content Knowledge and Pedagogical Content Knowledge

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This article seeks to present findings from the analysis of the TEDS-M reports on the mathematical content knowledge (MCK) and pedagogical content knowledge (PCK) of the pre-service teachers in Malaysia. The main objective of this study was to investigate the level of teaching knowledge attained by the Malaysian pre-service primary and secondary teachers. Some 576 primary level pre-service teachers and 389 secondary level pre-service teachers participated in the TEDS-M study. The significance of this study is pertinent as the level of teachers' knowledge influences students' achievement in schools. Results of analysis show that Malaysian pre-service teachers at the primary and secondary performed below the international average for both mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK). The article suggested several steps on how teacher educators could improve the PCK and MCK of pre-service teachers in Malaysia.

Keywords: Pre-service teachers, mathematical content knowledge, pedagogical content knowledge.

INTRODUCTION

One focus in the teaching and learning of mathematics in the 21st century is to have an effective lesson that engages students actively in the classroom (Anthony & Walshaw, 2009). In order to develop an effective mathematics lesson, pre-service mathematics teachers need to have adequate knowledge for teaching

mathematics. Knowledge for teaching mathematics requires not only content knowledge but also pedagogical content knowledge (Committee on the Study of Teacher Preparation Programs in the United States, 2010; Ponte & Chapman, 2008; Shulman, 1987).

According to the National Council of Teachers of Mathematics (NCTM), mathematics content knowledge is described as: "The content and discourse of mathematics, including mathematical concepts and procedures and the connections among them; multiple representations of mathematical concepts and procedures; ways to reason mathematically, solve problems, and communicate mathematics effectively at different levels of formality" (NCTM, 1991, p. 132). Kilpatrick, Swafford and Findell (2001) defined it as: "Knowledge of mathematical facts, concepts,

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State of the literature

- Ball, Thames, and Phelps (2005) described the mathematical knowledge for teaching (MKT) as knowledge of content and students as well as knowledge of content and teaching.
- Pedagogical content knowledge generally refers to the skill in teaching mathematics effectively. An, Kulm, and Wu (2004) described pedagogical content knowledge as consisting of three components such as the knowledge of content, knowledge of curriculum and knowledge of teaching
- The Teacher Education Development Study in Mathematics (TEDS-M) (Tatto et al., 2012) defined pre-service mathematics teachers' knowledge for teaching mathematics as comprising two components, namely mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK).

Contribution of this paper to the literature

- The main objective of this study was to investigate the level and depth of teaching knowledge attained by the Malaysian pre-service primary and secondary teachers.
- The significance of this study is pertinent as the level of teachers' knowledge influences students' achievement in schools.
- Results of analysis show that Malaysian pre-service teachers at the primary and secondary performed below the international average for both mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK).

procedures, and their relationships among them; knowledge of the ways that mathematical ideas can be represented; and the knowledge of mathematics as a discipline -- in particular, how mathematical knowledge is produced, the nature of discourse in mathematics, and the norms and standards of evidence that guide argument and proof" (p. 371). Teachers with firm mathematics content knowledge are able to present mathematics as a consistent and related structure (Ball & Bass, 2000).

Pedagogical content knowledge generally refers to the skill in teaching mathematics effectively. Many definitions of pedagogical content knowledge in mathematics teaching exist; An, Kulm, and Wu (2004) described pedagogical content knowledge as consisting of three components; (a) knowledge of content, (b) knowledge of curriculum and (c) knowledge of teaching. Likewise, Kilpatrick et al. (2001) delineated two categories of this knowledge, that is knowledge of

students and knowledge of practice. According to Anthony and Walshaw (2009), teachers' knowledge and beliefs about mathematics as well as their understanding of mathematics teaching and learning guide the organisation of classroom instruction.

Ball, Thames, and Phelps (2005) described the mathematical knowledge for teaching (MKT) as knowledge of content and students as well as knowledge of content and teaching. In addition, Hill, Rowan, and Ball (2005) defined it as mathematical knowledge for teaching which "is the mathematical knowledge used to carry out the work of teaching mathematics" (p. 273).

The MKT combines both the content knowledge and pedagogical content knowledge into a single definition. This differs from the other studies that make a clear distinction between content knowledge and the pedagogical content knowledge.

More recently, the Teacher Education Development Study in Mathematics (TEDS-M) (Tatto et al., 2012) defined pre-service mathematics teachers' knowledge for teaching mathematics as comprising two components, namely mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK). The MCK framework, which was derived from the Trends in Mathematics and Science Study (TIMSS) framework, consists of four knowledge domains (number and operations, algebra and functions, geometry and measurement, and data and chance) and three cognitive domains (knowing, applying and reasoning). The MPCK framework, which evolved from a review of literature and was informed by the Mathematics Teaching in the 21st Century Project (MT21) framework, consists of three domains, namely curricular knowledge, planning for teaching and learning, and enacting teaching and learning.

According to Tatto et al. (2012), there are two important reasons for studying and understanding the MCK and MPCK of pre-service teachers. "First, teachers' knowledge influences the mathematics achievement of their students (Baumert et al., 2010; Hill, Rowan, & Ball, 2005). Second, the knowledge that future teachers have acquired by the end of their final year of study may be a key indicator of the success of their teacher education program" (p. 129).

LITERATURE REVIEW

Ponte and Chapman (2006) identified a number of issues with pre-service elementary teachers' knowledge of mathematics: (1) procedural attachments that inhibit development of a deeper understanding of concepts related to the multiplicative structure of whole numbers; (2) influence of primitive, behavioural models for multiplication and division; (3) adequate procedural knowledge but inadequate conceptual knowledge of

division and sparse connections between the two; (4) incomplete representations and narrow understanding of fractions; (5) distorted definitions and images of rational numbers; (6) lack of ability to connect real-world situations and symbolic computations; (7) serious difficulties with algebra; (8) difficulty in processing geometrical information and lack of basic geometrical knowledge, skills and analytical thinking ability; and (8) inadequate logical reasoning. Through research carried out by Turnukul and Yesildere (2007) that focused on the competency of 45 pre-service primary mathematics teachers with regard to pedagogical content knowledge in mathematics, the findings suggested that it is important for pre-service mathematics teachers to possess a good grasp of both mathematics content knowledge and mathematics pedagogical content knowledge from their training. These studies described the major issues encountered by pre-service elementary mathematics teachers in acquiring the content knowledge and the pedagogical content knowledge.

Next, we move on with difficulties faced by pre-service teachers at the secondary level on the knowledge in teaching mathematics. Ponte and Chapman (2008) identified three areas of mathematics knowledge that have received significant attention from researchers, namely functions, decimals and word problems. Sánchez and Llinares (2003) investigated four pre-service teachers' ways of knowing the concept of functions and their images and they found that: (1) all of the participants saw the concept of function as a correspondence between sets but, for the purpose of teaching, they emphasized different aspects of the mathematical concept; and (2) the participants also thought about the modes of representation of functions in different ways. Tsamir and Ovodenko (2005) asked 56 pre-service teachers in a teacher preparation programme to complete three tasks addressing their concept images and concept definitions of points of inflection. They found that there were two sources of the pre-service teachers' image that is one rooted in their previous mathematical studies and another rooted in their daily life examples. In addition, most of the pre-service teachers' definitions were the "personal type" and not the "concept type" and they showed erroneous understanding of points of inflection as tangent equal to zero.

Using case study, Presmeg and Nenduardu (2005) investigated a pre-service teacher's use of representations of functions in solving algebraic problems involving exponential functions and the findings indicated that the participant only had an instrumental understanding of the concept. In their study of 553 pre-service elementary teachers' and 25 in-service teachers' (returning for an upgrade course) understanding of decimals, Stacey et al. (2001) concluded that one in five of the participants lacked

good content knowledge of decimals and could pass on their poor knowledge to students. Van Dooren, Verschaffel and Onghena (2003) studied 97 primary and secondary pre-service teachers' preferred strategies for solving word problems and their findings showed that: (1) about half of the primary pre-service teachers adaptively switched between arithmetic and algebra whereas the other half experienced serious difficulties with algebra; and (2) the secondary pre-service teachers clearly preferred algebra, even for solving very easy problems for which arithmetic would be appropriate. These few studies illustrated the lack of content knowledge in algebra among pre-service teachers would affect the quality of teaching mathematics.

Further, Ponte and Chapman (2008) identified three areas of pre-service teachers' knowledge of mathematics teaching that have received significant attention from researchers, namely children's mathematics knowledge, classroom communication and reform of mathematics curriculum or pedagogy. Klein and Tirosh (1997) evaluated pre-service and in-service teachers' knowledge of children's common difficulties with multiplication and division word problems involving rational numbers and the possible sources of difficulties. They found that: (1) almost all the in-service teachers provided correct expressions for the multiplication and division word problems, but this did not happen with the pre-service teachers; and (2) most of the pre-service teachers exhibited little knowledge of the difficulties children experienced with word problems involving rational numbers and possible sources of these difficulties. In a study to enhance pre-service elementary teachers' knowledge of children's conceptions of division of fractions, Tirosh (2000) found that: (1) before the course, the participants mentioned only the children's algorithmic or reading comprehension errors but after the course, they discussed the children's attempt to apply the properties of whole numbers directly to rational numbers; and (2) most of the participants had naive beliefs about teaching and learning. In their study of pre-service elementary teachers' understanding of decimals, Stacey et al. (2001) also studied their pedagogical knowledge in relation to students' errors and their findings indicated that: (1) the pre-service elementary teachers had only moderate understanding of their errors as being consistent with that of the students; (2) the participants who made errors on the test were more aware of potential student errors than the other participants; and (3) the participants were good at identifying features of decimal comparisons that led to students' errors but were not good at explaining why.

Crespo (2004) investigated how pre-service teachers interpreted students' work using mathematics letter exchanges with school students and found that: (1) the pre-service teachers initially tended to focus on the

correctness of their students' answers but, later, they focused on the students' mathematical abilities and attitudes; (2) they also became more analytical of the mathematics involved in the students' responses and exhibited greater attention to the meaning of students' mathematical thinking rather than the surface features of the students' work. Nicol (1999) who studied pre-service teachers' learning to teach mathematics in terms of questioning, listening and responding found that they seemed to be inclined to asking questions that focused on getting students to an answer and this seemed to be in tension with posing questions that might also elicit student thinking. But, they started to pose questions, listen and respond to their students differently as the course progressed. In an investigation of the conceptions and practices of communication in the classroom of two pre-service teachers, Brendefur and Frykholm (2000) found that the two participants had different teaching approaches and their classrooms depicted different forms of communication.

In a 3-year study of 6 cohorts of 63 pre-service secondary mathematics teachers' knowledge of the NCTM (1989) Standards contrasted with their teaching practices, Frykholm (1999) found that most of the participants reported detailed knowledge of the reform movement, recognized what reform-based instruction should look like, and valued the Standards as an orientation document but this was seldom evidenced in their teaching practices. In a 4-year longitudinal study, Steele (2004) followed four participants from the time they were pre-service primary teachers in a program incorporating a reform-based mathematics methods course to the end of their second year of teaching and found that only two of the four participants sustained their cognitively based conceptions about mathematics teaching and learning and implemented these conceptions into practice. All the studies discussed points to the importance of pre-service teachers having a solid content knowledge and adequate pedagogical content knowledge to ensure that effective mathematics teaching happen in the classrooms.

The findings of the TEDS-M (Tatto et al., 2012) indicated that the teaching mathematics knowledge that pre-service primary and secondary teachers acquire by the end of their teacher education knowledge generally varies considerably among individuals within every country and across countries. The difference in mean MCK scores between the highest- and lowest-achieving country in each primary and secondary program group was between 100 and 200 score points. The differences in mean MPCK scores across countries in the same program-group were somewhat smaller, ranging from about 100 to 150 score points. Thus, within each program group, and by the end of the teacher preparation programs, pre-service teachers in some countries had substantially greater MCK and MPCK

than others. On average, pre-service primary teachers being prepared as mathematics specialists had higher MCK and MPCK scores than those being prepared to teach as generalists. In addition, on average, pre-service teachers being prepared as lower and upper secondary teachers had higher MCK and MPCK scores than those intending to be lower secondary teachers.

Objectives

The main objective of this study was to investigate the level of teaching knowledge attained by the Malaysian pre-service primary and secondary teachers. This teaching knowledge includes the mathematical content knowledge (MCK) and the pedagogical content knowledge (MPCK) of the pre-service mathematics teachers. The secondary objective focused on whether there were any relationships between the mathematics content knowledge according to gender. Specifically, this study intends to address the following research questions:

- 1) What are the level and depth of the knowledge for teaching mathematics attained by Malaysian pre-service primary teachers?
- 2) What are the level and depth of the knowledge for teaching mathematics attained by Malaysian pre-service secondary teachers?
- 3) What is the relationship between the mathematics content knowledge and gender of pre-service primary teachers?

METHODOLOGY

The Teacher Education Study in Mathematics (TEDS-M) is a study conducted by the International Association for the Evaluation of Educational Achievement (IEA) in 2008. This study is the first international study to provide information on the knowledge of prospective primary and secondary school teachers obtained during their mathematics teacher education. TEDS-M also focused on mathematics teacher education policy of the participating countries. In the TEDS-M study, the 17 participating countries were: Botswana, Canada (four provinces), Chile, Chinese Taipei, Georgia, Germany, Malaysia, Norway, Oman (lower-secondary teacher education only), the Philippines, Poland, the Russian Federation, Singapore, Spain (primary teacher education only), Switzerland (German-speaking cantons), Thailand, and the United States of America (public institutions only). The researcher was granted permission to utilise the data provided from the IEA database.

A total of 524 final year pre-service primary teachers and 388 pre-service teachers in Malaysia participated in the TEDS-M study. In Malaysia, primary teachers were trained as mathematics specialists whereas the secondary

teachers were capable of teaching lower and upper secondary mathematics. TEDS-M selected educational institution samples randomly from all the teacher training institutes and universities. Pre-service teachers from these educational institutions were required to complete the questionnaire instrument that includes an achievement test on mathematics teaching knowledge. The details of the sampling procedure, demographics and the mathematical items could be found in the TEDS-M report (Tatto et al., 2012). In this paper, the data on mathematics for teaching knowledge were analyzed using linear regression, correlation and t-test.

RESULTS

The results of this study are discussed in the following sections according to the research questions:

Level and Depth of the Knowledge for Teaching Mathematics Attained by Malaysian Pre-Service Primary Teachers

Table 1 reports the pre-service primary teachers' mathematics content knowledge of several countries. Malaysian primary pre-service teachers recorded a mean score of 488 from a maximum score of 800 with a standard error of 2.00. The mean score is way below the international mean score of 520 from the 17 participating countries.

Two anchor points were defined for the primary level MCK scale. Anchor Point 1 corresponds to a score of 431 and represents a lower level of MCK. Anchor Point 2 is the score of 516 and refers to the higher level of knowledge (Tatto et al., 2012). Teachers at Anchor Point 1 would face difficulty in solving abstract problems, solving multiple steps problems and tend to over-generalize. Some 88.7% of Malaysian pre-service teachers are at or above the score of Anchor Point 1 which indicated that most Malaysian teachers have the basic MCK.

Teachers at Anchor Point 2 would do well on items on standard problems and the cognitive domain of knowing. However, they would struggle at non-routine

problems and problems involving complex reasoning (Tatto et al., 2012). Only 28.1% of Malaysian pre-service teachers achieved the score of Anchor Point 2. This implies that pre-service teachers in Malaysia were weak in solving complex problems. This is worrying for Malaysians as only slightly more than a quarter of the pre-service teachers have high level of MCK. Steps must be taken to improve the MCK curriculum in Malaysia for primary pre-service teachers to enhance their content knowledge.

Table 2 shows the pre-service primary teachers mathematics pedagogical content knowledge (MPCK) of several countries. Malaysian primary pre-service teachers reported a mean score of 503. This is lower than the international mean of 551. Only one anchor point was defined at the primary level for the MPCK scale with the score of 544. This is due to the small number of MPCK items in the instrument. Pre-service teachers who scored at or above this anchor point were likely to recognize whether the teaching strategies work and to evaluate students' work. However, they were unlikely to be aware of common misconceptions and were unlikely to use concrete representations (Tatto et al., 2012). Only 23.4% of pre-service teachers in Malaysia scored at or above this anchor point. This shows that Malaysian pre-service teachers were quite weak in their MPCK knowledge.

Level and Depth of the Knowledge for Teaching Mathematics Attained by Malaysian Pre-Service Secondary Teachers

Some pre-service secondary teachers in Malaysia had taken this instrument testing their mathematics content knowledge (MCK). Table 3 reported the pre-service secondary teachers mathematics content knowledge of several countries. Anchor Point 1 corresponds to a score of 490 representing a lower level of MCK while Anchor Point 2 corresponds to a score of 559 representing a higher level of MCK. Anchor Point 1 teachers would generally be able to solve number and simple geometric problems but face problems with multi-step problems and describing general patterns .

Table 1. Pre-Service Primary Teachers Mathematics Content Knowledge (MCK) from the TEDS-M International Report (Exhibit 5.10, P.139)

Primary specialist	Sample (N)	Percentage at or above Anchor point 1 (SE)	Percentage at or above Anchor point 2 (SE)	Scaled score Mean (SE)
Malaysia	574	88.7(1.1)	28.1(1.3)	488(2)

Table 2. Pre-Service Primary Teachers Mathematics Pedagogical Content Knowledge (MPCK)

Primary specialist	Sample (N)	Percentage at or above Anchor point (SE)	Scaled score Mean (SE)
Malaysia	574	23.4(1.9)	503(3)

Table 3. Pre-Service Secondary Teachers Mathematics Content Knowledge (MCK)

Lower and Upper Secondary	Sample (N)	Percentage at or above Anchor point 1 (SE)	Percentage at or above Anchor point 2 (SE)	Scaled score Mean (SE)
Malaysia	388	57.1(2.3)	6.9(0.9)	493(2)

Table 4. Pre-Service Secondary Teachers Mathematics Content Knowledge (MCK)

Lower and Upper Secondary	Sample (N)	Percentage at or above Anchor point (SE)	Scaled score Mean (SE)
Malaysia	388	27.9(2.5)	472(3)

Table 5. Pre-Service Primary Teachers Regression Analysis with Achievement Scores

	N of cases	Constant (estimate)	Constant (s.e.)	Gender (estimate)	Gender (s.e.)	t-test value	Sig.
Malaysia	574	490.64	2.14	4.87	1.84	2.64	0.000

* significant at $p < .05$

Pre-service teachers who scored at Anchor Point 2 could do most of the mathematics correctly as compared to Anchor 1 teachers. Anchor 2 teachers know some definitions and theorems of calculus, geometry and abstract algebra (Tatto et al., 2012).

Malaysian teachers obtained a mean score of 493 which is lower than the international mean of 530. In addition, 57.1% of Malaysian pre-service teachers were at the lower level of MCK whereas only 6.9% were at the higher level of MCK. To improve the MCK knowledge of Malaysian teachers, an examination on mathematics content could be introduced at the end of the teacher education program.

Table 4 reports the pre-service secondary teachers mathematics pedagogical content knowledge (MPCK) of several countries. Malaysian teachers achieved a mean score of 472 which is lower than the international mean of 520. The anchor point score is 509.

At this point, secondary teachers were likely to have some knowledge on the curriculum planning for instruction and evaluating students' work correctly. However, these teachers lack a well developed meaning of mathematical argument causing and analysing students errors (Tatto et al., 2012). Only 27.9% of pre-service secondary teachers in Malaysia achieved the Anchor Point. This again showed that Malaysian pre-service secondary teachers were lacking in their MPCK knowledge.

The Relationship between the Mathematics Content Knowledge and Gender of Pre-Service Primary Teachers

In this section, the relationship between the mathematics content knowledge and gender of pre-service primary teachers was analyzed using linear regression. For this regression analysis, the independent variable or predictor was the pre-service primary

teachers gender and mathematics content knowledge (MCK) as the dependent variable. A t-test was also done to determine whether the average mathematics knowledge was significantly different between females and males.

Table 5 showed the regression analysis of the pre-service primary teachers. The estimated average mathematics knowledge for female pre-service teachers was 490.64. The differences between the mean score of the females and male pre-service teachers group in Malaysia are moderate difference of 4.87 score points. The standard errors for the constant and the slope are very small at 2.14 and 1.87 respectively. Results show that the female teachers performed better than the male teachers in Malaysia in the achievement test by a score of 4.87 points. There were statistically significant differences between female and male pre-service secondary teachers in Malaysia as the t-test value is greater than 1.96 for a two-tailed test and the p-value is less than 0.05.

DISCUSSION

Malaysian primary pre-service teachers recorded a mean score of 488 for the mathematics content knowledge (MCK) achievement test. The mean score is way below the international mean score of 520. Only more than a quarter of the pre-service teachers have a high level of MCK and this is an issue of concern in primary teacher education. Similarly, the primary pre-service teachers reported a mean score of 503 in the mathematics pedagogical content knowledge (MPCK) that is also lower than the international mean of 551. Malaysian pre-service teachers were quite weak in their MPCK knowledge. This is worrying as these are the future primary teachers who would be teaching in Malaysian schools in the near future.

These results might indicate the weakness in the teacher education curriculum for Malaysian primary mathematics teachers. It is important that pre-service teachers possess strong content knowledge and pedagogical content knowledge from their teacher preparation program (Tumukul & Yesildere, 2007). Producing quality mathematics teachers is stated explicitly in the Malaysia Education Blueprint 2013-2025. Currently, there is an entrance examination to select future primary teachers. The education authorities could introduce an exit examination on the content knowledge and pedagogical content knowledge for pre-service teachers. This would ensure the quality in content knowledge of pre-service teachers. Another suggestion would be introducing the teaching licensing board where future teachers need to fulfil the requirement of content and pedagogical knowledge before they can start teaching in schools.

At the secondary level, Malaysian teachers obtained a mean score of 493 for mathematics content knowledge (MCK) which is lower than the international mean of 530. In addition, 57.1% of Malaysian pre-service teachers were at the lower level of the mathematics content knowledge (MCK) whereas only 6.9% of pre-service teachers were at the higher level of MCK. This is worrying as teachers who lack good content knowledge could pass on their poor knowledge to their students (Stacey et al., 2001). An exit examination on mathematics content knowledge should be introduced for pre-service teachers to be certified as mathematics teacher.

In the mathematics pedagogical content knowledge (MPCK), Malaysian secondary teachers achieved a mean score of 472 which is lower than the international mean of 520. Only 27.9% of pre-service secondary teachers in Malaysia achieved the moderate level of mathematics pedagogical content knowledge. This is a major concern as the other 82.1% of pre-service teachers have a low MPCK level which could affect lesson delivery (Nicol, 1999). Effective teachers with strong MPCK would be able to explain the "why" questions in lessons that improve students' understanding of mathematical concepts. (Stacey et al., 2001). As secondary school teachers were trained in universities, including class observations and co-teaching with experienced teachers in the teaching practicum will improve their MPCK. The curriculum of teacher education program should also be enhanced to address the problem of pre-service teachers' poor MCK. Another suggestion would be to prolong the duration of teaching practice for pre-service to 1 full year instead of the current 14 weeks. This would provide student teachers with some experience in improving their MPCK.

The relationship the mathematics content knowledge and gender of pre-service primary teachers was analyzed using linear regression. The differences in

the mean score between female and male teachers were statistically significant favouring the female pre-service teachers. Results show that the female teachers performed better than the male teachers in the achievement test by the score of 4.87 points. This is a concern to the country as there seems to be an achievement gap in content knowledge between male and female teachers. The difference might be due to the higher percentage of women among the primary teachers. It will be good to encourage males to be mathematics teachers at the primary level. In the Malaysian Education Blueprint 2013-2025, the government intends to recruit the top 30% of applicants to be teachers.

CONCLUSION

The secondary analysis of the TEDS-M results indicated that Malaysian pre-service mathematics teachers at both the primary and secondary level have low mathematics content knowledge. Similarly, the pre-service teachers also have lower score than the international average in pedagogical content knowledge. This is worrying as these are the future teachers who would be teaching in Malaysian schools in the near future Steps have to be taken by the education authorities to address this problem because schools need teachers with strong content knowledge and pedagogical content knowledge to deliver effective mathematics lessons.

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