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The Content Knowledge and the Teacher Readiness of Teaching Secondary School Quantum Physics in Sabah

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Abstract. Modern technological applications made quantum physics (QP) an important subject to include in secondary school curricula in other countries before it did so in Malaysia. Secondary school students in our county will be educated using the new, revised curriculum when QP goes into effect in 2021. Consequently, a study was done to determine the level of content knowledge and teacher readiness for teaching secondary school quantum physics in Sabah. A cross-sectional survey method was used to gather data from a sample of 175 Sabah Form Five Physics teachers, who were chosen through a multistage cluster sampling process. The research instrument used an adapted and modified questionnaire. The reliability values of this instruments were high at .87. The IBM SPSS version 28.0 software was used to analyze the study data. According to the findings of the study, physics teachers have a moderate level of content knowledge (m = 6.78) and teacher readiness (m = 6.96). Using the data from this study, the Malaysian Ministry of Education and policymakers can get a clear image of how prepared Physics teachers are for QP implementation once it is implemented in 2021.The implications of the study show that content knowledge towards teacher readiness of teaching secondary school QP is crucial to improve the quality of QP teaching.

Keywords: Content knowledge, Physics teacher, Teacher readiness, Secondary school, Quantum Physics

INTRODUCTION

Secondary school curricula around the world have been teaching students about quantum physics (QP) for some time now, owing to its importance in modern technology applications. New curricula have been implemented in our secondary schools since 2021, when QP will come into effect (KSSM). There has been some delay in implementing teacher education as planned because of changes made to the curriculum. According to a study on teacher readiness, content knowledge is a crucial component (Park et al., 2016). Content knowledge is also included in the study by Fan et al. (2019) as an important part of being a ready teacher. To teach QP, the teacher needs to have a better understanding of the subject matter. Teacher training should be extensive and high-quality to ensure that they don't feel excluded or unjust as a result of the implementation of the new curriculum, according to Balta (2018).

Teachers must have a good understanding of quantum physics (QP) in order to incorporate it into the physics curriculum. According to a study by Balta (2018), teachers are not ready to teach QP because they lack a full comprehension of the issues covered in the curriculum. Teachers should have a thorough understanding of the subject matter they will be teaching before attempting to teach QP. The new revamped curriculum suggests that teachers' content knowledge influences their readiness to teach QP in secondary schools to a greater or lesser extent. Students will benefit from improved comprehension if teachers' needs are met in this way. This is a serious constraint, as prior studies on QP research have mainly been conducted at the graduate level of education. In addition, prior studies have shown conclusions about the quantum physics understanding of university students (Calýskan et al., 2009). Quantum physics in secondary schools isn't the only subject studied in terms of teacher readiness for science and math in general. As a result of this, this study will examine the content knowledge of physics teachers on QP and their readiness to teach QP to secondary school students.

IMPLEMENTATION OF SECONDARY SCHOOLS QUANTUM PHYSICS

Quantum physics (QP) was taught to college students long before it was taught in secondary schools today. Because QP is a fundamental theory of physics, it should be taught in secondary school. In other words, it's a lot of work. For students between the ages of 17 and 19, quantum physics (QP) has already been included in their physics curricula in Australia, France, and Norway (Stadermann et al., 2019). Since 2016, secondary school students in the Netherlands have had the opportunity to learn about QP through the school's curriculum (Krijtenburg-Lewrissa, 2020). Because of the conceptual and applied importance of QP, secondary school physics curricula have been modified as a result of its implementation in the curriculum (Krijtenburg-Lewerissa et al., 2019).

The Standard Curriculum for Primary Schools (*KSSR*) was unveiled by the Malaysian Ministry of Education in 2011. In order to maintain a smooth transition between primary and secondary education, the content of the primary school curriculum is being included into the secondary school curriculum (*KBSM*). It is important to keep *KBSM* up to date and relevant to the demands of the twenty-first century while also connecting it with the government's transformation strategy. The Secondary School Standard Curriculum (*KSSM*) is a brand-new programme. Students should know what they should know at a certain point in time and degree of education, according to the KSSM. Content, learning, and performance are the three requirements for each level. Among the changes are changes to the structure of curriculum materials, instructional elements, and assessments (Bahagian Pembangunan Kurikulum, 2016). In the past, the Integrated Secondary School Curriculum (*KBSM*) was used in physics curriculum standards. It was first used in schools in 1989. 2017 saw the end of the Secondary School Physics Document Standard. It was replaced by the Secondary School Physics Document Standard (Bahagian Pembangunan Kurikulum, 2018). To make sure that this national curriculum is up to date with the Malaysian Education Blueprint 2013-2025, it is being changed (Ministry of Education Malaysia, 2012). They can learn more about *KSSM* by looking at curriculum frameworks, learning areas, cross-curricular aspects and how the curriculum is put into practise. Secondary School Curriculum Standards (*KBSM*) was changed to Secondary School Curriculum Standards after the Ministry of Education did this. A whole new topic was added to the physics curriculum (*KSSM*).

Students and teachers both face difficulties with QP, despite its importance in the secondary school curriculum (Michelini et al., 2014). The underlying idea of QP, which differs greatly from mainstream physics, is at the core of the challenge. One of the differences between QP and classical physics is that QP's mathematical components are more challenging than classical physics' computations (Pospiech, 2019). Students are interested in quantitative probability, according to the conclusions of the Stadermann and Goedhart, (2020) study. The fact that so many questions remain unanswered about quantum mechanics, for example, has led some students to claim that the field is more enigmatic than classical physics. Because of the usefulness of QP, many experts believe that it should be included in the secondary school physics curriculum, regardless of how difficult it may be to comprehend. Due to the fact that most teachers lack a foundation in QP, they have difficulty teaching the subject matter (Lautesse et al., 2015). As a result, teachers have become less confident about their ability to teach this subject if they rely on textbooks instead of teaching it themselves (Wook Cheong & Song, 2014). QP uses the phrase "wave and particle" to describe the wave and particle characteristics that differ from those of classical physics. Due of this challenge, Bungum et al. (2015) discovered that teachers require a large number of readily available quality assurance materials. Understanding photon wave-particle duality and Heisenberg's uncertainty principle requires understanding quantum physics (Wook Cheong & Song, 2014). Due to constraints, doing QP experiments in a secondary school lab is difficult. According to Daniela et al. (2015), some topics, like the Plank constant experiment, can be completed affordably. Many QP experiments may be done easily and inexpensively in secondary schools to help pupils comprehend QP phenomena. The issues of teaching and learning about QP topics have been addressed in previous research.

Physics experts have provided recommendations for secondary physics curricula based on previous QP research. According to Stadermann et al. (2019), most countries used the same 17 QP subjects in their upper secondary physics curriculum from 15 other countries. Further research demonstrated that our physics curriculum's QP principles are suited for secondary school students. Teaching QP needs teachers to be knowledgeable in the subject and prepared to cope with QP's challenging subjects. In our setting, teachers will be teaching the topics by 2021 begin with the history of quantum theory, Plank theory, blackbody radiation, wave particle duality, concept of photon, Einstein's photoelectric theory and the application of QP in daily life.

TEACHER READINESS TO TEACH QUANTUM PHYSICS

When a new topic or curriculum is introduced into the classroom, the teacher's readiness to teach and learn is crucial. It is a stage of preparation where teachers have a positive outlook on the transition and a desire to work for the benefit of students in their future roles (Fan et al., 2019; Holt & Vardaman, 2013). Apart from that, the maturity and experience of a teacher indicate whether or not they are ready to teach (Du & Chaaban, 2020; Rauf et al., 2019). Teacher readiness can also be defined as preparing teachers for roles that need their passions, perceptions, attitudes, expertise, and competencies (Al-Awidi & Aldhafeeri, 2017). On the other hand, teachers' readiness to implement change in school, according to Weiner (2009), can be affected by a number of factors, such as their awareness of the change, attitudes, motivation, and knowledge of and capacity to adapt to the shift in question.

Previous research found that content knowledge was an important component in determining teacher readiness. A teacher's content knowledge, pedagogical content knowledge, and curriculum knowledge are all included in Shulman's conception of teacher knowledge, according to (Shulman, 1987). Content knowledge is also known as teacher epistemology knowledge, and it encompasses not just what teachers learn in the classroom but also what they learn from their students (Jwaifell, 2019). Researchers Hasan and Daud (2020) found that students benefit from teachers who have a thorough understanding of their subject matter because they are better able to apply that information to real-world circumstances, which makes the content more understandable for them in the classroom. Teachers with these attributes are eager to teach their students any new subject. In a questionnaire-based study, having a high level of content knowledge leads to a high level of teacher preparedness (Huoy Tyan et al., 2020; Rohaida, 2017). The findings of the study show that when teachers have a high degree of content knowledge, they supply more teaching resources to create a more enjoyable learning environment.

In addition, once the teacher has achieved content understanding, he or she will be able to modify activities in order to assist the students' learning. (Nilsson & van Driel, 2011). However, pedagogical content knowledge is one of the factors that determines whether or not a teacher is ready to teach in addition to subject matter expertise (Chieng & Tan, 2019; Mousa, 2016). The idea of pedagogical content knowledge was developed by Shulman (1987) in response to his claim that teachers have a knowledge gap when it comes to subject matter. This example shows how teachers can use pedagogical subject knowledge in the classroom before they can connect the topic knowledge with pedagogical and curriculum knowledge, as shown. It has been shown that teachers who lack a strong foundation in pedagogical content are unable to improve their skills as they progress through their careers (Widodo, 2017). The outcomes of a study conducted by Kleickmann et al. (2017), however, show that pedagogical content knowledge can only improve if teachers have a thorough understanding of their subject matter. Teachers who don't know their stuff aren't able to communicate effectively with their students, according to the research. Whether or not the new curriculum is a success will largely depend on how well-prepared teachers are to implement it. To stay on top of global education trends, curriculum is always evolving to meet the needs of national education systems.

RESEARCH FRAMEWORK

The conceptual framework in Figure 1 illustrates the conceptual framework of this study. The conceptual framework of this study is the combination of Shulman conceptualization of teacher knowledge and Weiner's theory to determine the level of teacher readiness to teach QP in terms of their content knowledge. The integration of Shulman conceptualisation of teacher knowledge and Weiner's readiness to change theory will assist this study to obtain the outcome of the study according to the objectives of this research.

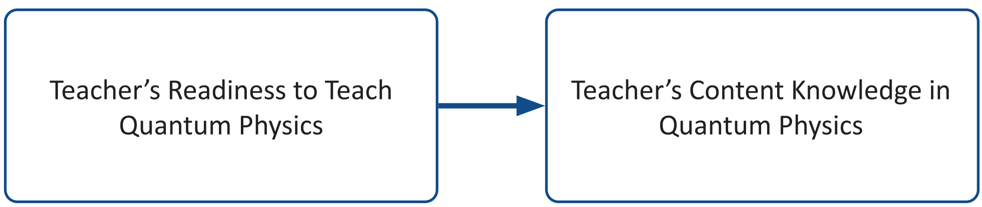

Figure 1 The conceptual framework for factor influencing the level of teacher readiness to teach physics secondary school quantum physics in Sabah

The conceptual framework of the study as shown in the Figure 1 describes the objectives of the study as a whole. Firstly, is to identify the level of physics teachers content knowledge to teach quantum physics. Secondly, to identify the level of teacher readiness of teaching quantum physics in secondary schools.

METHODOLOGY

Research Design. Following a quantitative research design, this study employed a deductive approach and administered survey questionnaire to describe the influence of content knowledge towards the level of teacher's readiness of teaching secondary schools QP. This study reflects a positivist view based on hypothetico-deductive method which means to verify the hypotheses which are frequently stated in quantitative terms of functional relations between causal and explanatory factors (independent variables) and outcomes (dependent variables) (Park et al., 2019).This design is suitable in allowing researcher to achieve the aims of the study primarily in examining relationship between two variables as it follows a standardized procedure of ensuring reliability and validity of the instruments that seek to respond the specified research questions and test related hypotheses (Yan Piaw, 2020).

Sampling. For the purpose of this study, the current study's population consisted of Form Five Physics instructors in Sabah. The teachers involved come from a total of 24 districts across six zones in Sabah. Due to the large geographical area of Sabah, this study employed multistage cluster sampling followed by simple random sampling. 175 responses from physics teachers were deemed eligible for data analysis after data cleaning.

Table 1 presents the demographic information of the participants, which include their gender, zone in Sabah, experience and did they study QP in their undergraduate studies.

Table 1 Demographic information of participants

	Category	Frequency	Percentage, %
Gender	Male	73	41.7
	Female	102	58.3
Zone in Sabah	1	40	22.9
	2	28	16.0
	3	28	16.0
	4	28	16.0
	5	19	10.9
	6	32	18.3
Years of teaching Physics	Less than 5 years	22	12.6
	5 – 10 years	50	28.6
	11 – 20 years	77	44.0
	21 – 30 years	26	14.9
Have studied QP in undergraduate studies	Yes	116	66.3
	No	59	33.7

Table 1 presents the demographic information of the participants. It shows that 41.7% are male, while the remaining 58.3% are females. 22.9% participants are from Zone 1, 16.0% of the participants are from Zone 2, 3 and 4 respectively while 10.9% of the participants from Zone 5, lastly 18.3% of the participants from Zone 6. For their experience in teaching Physics, 12.6% of the respondents have experience less than 5 years, 28.6% of the respondents has an experience of between 5 to 10 years, 44.0% have their experience between 11 to 20 years while 14.9% has an experience between 21 to 30 years. Most of the respondents (66.3%) have QP background in their undergraduate studies while the remaining 33.7% of the respondent did not have QP background.

Instrumentation. A survey questionnaire containing 31 items was used to obtain information from the respondents. The ítems in the study's questionnaire were adapted and adopted with permission from the authors and modified accordingly to fit the research objectives. Moreover, the questionnaire is divided in three sections: Demographic information of respondents; Content Knowledge and Teacher Readiness. The questionnaire was based on ten-point interval scale with the following descriptors: Strongly Agree=10 and Strongly Disagree=1.

For the validity of the instruments, this instruments have been validated via two physics education experts who were familiar with the content knowledge of QP and three statistics experts who were familiar with constructs validity. In the study by Planinic et al. (2019), they asserted that physicists have been using the Rasch model for data analysis for a long time. Thus, the Rasch Measurement Model (RMM) is an effective solution for preparing high validity and reliability of the instrument by producing detailed statistics (Bond & Fox, 2015). RMM assessed each respondent's ability to answer the instrument and measured the difficulty of each item on the instrument (Green & Frantom, 2002). The instrument reliability based on the alpha coefficient (KR-20) of the Cronbach (Cronbach) is .87. This value shows that the questionnaire's reliability is high (Sumintono & Widhiarso, 2015).

A Google Form was used to create an online questionnaire. The online instrument would enable a broader range of respondents to be reached throughout the state, as it can be easily distributed to the targeted respondent via a link shared on various sharing platforms. The questionnaires were distributed to 180 Physics teachers in Sabah via Google Form link after getting permission for collecting data. The teachers who participated voluntarily in this study were asked to answer all questions carefully and honestly based on their experiences and perceptions of the implementation of QP in secondary school's curriculum. After one month, 178 response of the survey was collected. After data cleaning and considering all outliers, a total of 175 questionnaires were tallied for this study.

Data Analysis Method. The collected data were analyzed using SPSS (V.28) software for descriptive statistic. Frequencies and percentages were used to get information about the background of the respondents, as well as the level of of their content knowledge and readiness of teaching secondary schools QP.

FINDINGS

The survey instruments were intended to study the Physics teachers' level of content knowledge of QP and their level of readiness of teaching secondary schools QP. The total mean score for each section based on constructs is tabulated in Table 2. Based on Table 2, majority of the respondents were medium high in their content knowledge (M = 6.78, SD = 0.73) in regard to QP topics. On the other hand, the finding also shows that majority of the respondents possesses medium high of readiness (M = 6.96, SD = 0.74) on the QP implementation in secondary school physics curriculum.

Table 2 Total mean score on section based on this survey

Section	Mean	SD
Physics teachers' content knowledge of QP	6.78	0.73
Physics teachers' readiness to teach QP	6.96	0.74

Data presented on Table 3 shows that majority of the respondents admitted that they had unclear understanding on two items in the section 2.

Table 3 The lowest mean score for Section 2

Section 2: Teachers' Content Knowledge	Mean	SD
Electrons are always behaving as particles.	3.71	2.03
Light always behaves as waves.	3.91	2.40

Based on Table 4, majority of the respondents plan to prepare same set of questions for all level of achievement in learning of QP (M = 3.39, D = 1.79). On the other hand, respondents do score low in their readiness to visualize abstract quantum phenomena to students (M = 3.64, SD = 2.08).

Table 4 The lowest mean score for Section 3

Section 3: Teachers' Readiness to teach QP	Mean	SD
I plan to prepare same set of questions for all level of achievement in learning of quantum physics.	3.39	1.79
I plan to draw in the teaching and learning process to visualize abstract quantum phenomena to students.	3.64	2.08

DISCUSSION

Teachers' Content Knowledge on Quantum Physics. The finding of this research reveals that teachers have a moderately high level of content knowledge regarding QP. This demonstrates that, despite their initial knowledge of QP, many teachers continue to have doubts about the fundamental properties of QP. The two items with the lowest means show that teachers uncertain about the duality properties of electron and light respectively. This is also has been found in the study by Héraud et al., (2017) whereby wave duality properties has been a challenge to teachers' understanding. However, this study found that most teachers' have medium high level of understanding towards the concepts of electron, structure of atom and the phenomena of QP. In order to make sure teachers have more confidence when delivering QP topic content, teachers have to put efforts to ensure that the level of understanding about the theory and teaching methods for QP topics may be increased (Balta, 2018).

Teachers' Readiness of Teaching Secondary Schools Quantum Physics. Since QP is a newly added topic to the physics curriculum, teacher readiness to teach it in secondary schools is dependent on the teacher's maturity and experience (Du & Chaaban, 2020b; Kondakci et al., 2015). Teacher readiness of teaching this topic is also defined as the willingness of the teacher to take on responsibilities that cover aspects such as interests, attitudes, knowledge and skills of the regarding topic (Wearmouth et al., 2000). The findings of this study found that there are two items of teacher readiness that have the lowest mean score. The two items were related to the preparation of a common set of questions for all levels of student achievement in QP learning in the classroom. While the other item is related to the description of abstract quantum physics phenomena through drawings on the whiteboard to give a clear picture to students during the learning and teaching process. The abstract QP cannot be clearly explained to students solely through drawings alone, explanations need to use simulations to help students to better understand (Kalkanis *et al.*, 2003; Kohnle *et al.*, 2010; Müller & Wiesner, 2002). Therefore, teachers need to be better prepared in terms of proactive teaching techniques.

IMPLICATION AND CONCLUSION

The purpose of this study is to determine the level of content knowledge and readiness of physics teachers to implement QP in secondary school physics curriculum. The findings of this study may provide educational stakeholders with an up-to-date image of Physics teachers' content knowledge and readiness for QP implementation. This study proposes that Physics teachers take proactive measures to maintain their level of content knowledge on the newly introduced topic in Physics KSSM, as this may have a significant impact on their readiness to implement the QP in the physics curriculum. In terms of future research, this study can be applied to broader facets of Malaysia's current secondary school curriculum. For instance, the study might be undertaken with a bigger sample size to ensure that the results have a wider impact and that generalisation to a larger population is achievable. Finally, it is advised that this study be replicated using a mixed methods approach to enable researchers to acquire a more comprehensive understanding of Physics teachers' level of content knowledge and readiness for newly added topics in secondary school physics curricula.

REFERENCES

Bahagian Pembangunan Kurikulum. (2016). *Buku Penerangan Kurikulum Standard Sekolah Menengah (KSSM)*. Bahagian Pembangunan Kurikulum , Kementerian Pendidikan Malaysia.

Bahagian Pembangunan Kurikulum. (2018). *Kurikulum Standard Sekolah Menengah Fizik Dokumen Standard Kurikulum dan Pentaksiran Tingkatan 4 dan 5*. bahagian Pembangunan Kurikulum, Kementerian Pendidikan Malaysia.

Balta, N. (2018). High School Teachers' Understanding of Blackbody Radiation. *International Journal of Science and Mathematics Education*, *16*(1), 23 – 43. https://doi.org/10.1007/s10763-016-9769-z

Bond, T. G., & Fox, C. M. (2015). *Applying the Rasch Model Fundamental Measurement in the Human Sciences Third Edition* (Third). Taylor & Francis.

Bungum, B., Henriksen, E. K., Angell, C., Tellefsen, C. W., & Bøe, M. V. (2015). ReleQuant – Improving teaching and learning in quantum physics through educational design research. *Nordic Studies in Science Education*, *11*(2), 153. https://doi.org/10.5617/nordina.2043

Calýskan, S., Selçuk, G. S., & Erol, M. (2009). Student Understanding of Some Quantum Physical Concepts. *Latin-American Journal of Physics Education*, *3*(2), 202 – 206.

Chieng, Y. E., & Tan, C. K. (2019). Validation and Reliability of Teacher Readiness, Technology and Pedagogy Knowledge Towards Technology Integration in 21St Century Learning. *International Journal of Education, Psychology and Counseling*, *4*(33), 41 – 52. https://doi.org/10.35631/ijepc.433004

Daniela, C. C., Popescu, F. F., Ioan, P. A., & Andrei, V. (2015). Conceptual Maps and Integrated Experiments for Teaching/Learning Physics of Photonic Devices. *Procedia - Social and Behavioral Sciences*, *191*, 512 – 518. https://doi.org/10.1016/j.sbspro.2015.04.284

Du, X., & Chaaban, Y. (2020a). Teachers' Readiness for a Statewide Change to PjBL in Primary Education in Qatar. *Interdisciplinary Journal of Problem-Based Learning*, *14*(1), 1 – 15. https://doi.org/10.14434/ijpbl.v14i1.28591

Du, X., & Chaaban, Y. (2020b). Teachers' Readiness for a Statewide Change to PjBL in Primary Education in Qatar. *Interdisciplinary Journal of Problem-Based Learning*, *14*(1). https://doi.org/10.14434/ijpbl.v14i1.28591

Fan, M., Leung, L. P., Leung, R., Hon, S., & Fan, K. L. (2019). Readiness of Hong Kong secondary school teachers for teaching cardiopulmonary resuscitation in schools: A questionnaire survey. *Hong Kong Journal of Emergency Medicine*, *26*(3), 174 – 178. https://doi.org/10.1177/1024907918797532

Green, K. E., & Frantom, C. G. (2002). Survey Development and Validation With the Rasch Model. *International Conference on Questionnaire Development, Evaluation, and Testing*, *February*, 42.

Héraud, J. L., Lautesse, P., Ferlin, F., & Chabot, H. (2017). Representing the Quantum Object Through Fiction in Teaching: The Ontological Contribution of Gamow's Narrative as Part of an Introduction to Quantum Physics. *Science and Education*, *26*(3 – 4), 299 – 322. https://doi.org/10.1007/s11191-017-9890-6

Holt, D. T., & Vardaman, J. M. (2013). Toward a Comprehensive Understanding of Readiness for Change: The Case for an Expanded Conceptualization. *Journal of Change Management*, *13*(1), 9 – 18. https://doi.org/10.1080/14697017.2013.768426

Huoy Tyan, P., Abd Rahman, F., & Shafie Sarvestani, M. (2020). Teachers' readiness in implementing and facilitating 21st century learning. *Universal Journal of Educational Research*, *8*(1 A), 24 – 29. https://doi.org/10.13189/ujer.2020.081304

Jwaifell, M. (2019). In-service Science Teachers' Readiness of Integrating Augmented Reality. *Journal of Curriculum and Teaching*, *8*(2), 43. https://doi.org/10.5430/jct.v8n2p43

Kalkanis, G., Hadzidaki, P., & Stavrou, D. (2003). An Instructional Model for a Radical Conceptual Change Towards Quantum Mechanics Concepts. *Science Education*, *87*(2), 257 – 280. https://doi.org/10.1002/sce.10033

Kleickmann, T., Tröbst, S., Heinze, A., Bernholt, A., Rink, R., & Kunter, M. (2017). *Teacher Knowledge Experiment: Conditions of the Development of Pedagogical Content Knowledge* (Issue June 2018). Springer International Publishing AG. https://doi.org/10.1007/978-3-319-50030-0_8

Kohnle, A., Douglass, M., Edwards, T. J., Gillies, A. D., Hooley, C. A., & Sinclair, B. D. (2010). Developing and evaluating animations for teaching quantum mechanics concepts. *European Journal of Physics*, *31*(6), 1441 – 1455. https://doi.org/10.1088/0143-0807/31/6/010

Kondakci, Y., Beycioglu, K., Sincar, M., & Ugurlu, C. T. (2015). Readiness of teachers for change in schools. *International Journal of Leadership in Education*, *20*(2), 176 – 197. https://doi.org/10.1080/13603124.2015.1023361

Krijtenburg-Lewerissa, K., Pol, H. J., Brinkman, A., & van Joolingen, W. R. (2019). Key topics for quantum mechanics at secondary schools: a Delphi study into expert opinions. *International Journal of Science Education*, *41*(3), 349 – 366. https://doi.org/10.1080/09500693.2018.1550273

Krijtenburg-Lewrissa, K. (2020). *Teaching Quantum Mechanics at Secondary Schools*. University of Twente.

Lautesse, P., Vila Valls, A., Ferlin, F., Héraud, J. L., & Chabot, H. (2015). Teaching Quantum Physics in Upper Secondary School in France: : 'Quanton' Versus 'Wave–Particle' Duality, Two Approaches of the Problem of Reference. *Science and Education*, *24*(7 – 8), 937 – 955. https://doi.org/10.1007/s11191-015-9755-9

Michelini, M., Santi, L., & Stefanel, A. (2014). Teaching modern physics in secondary school. *Proceedings of Science*, *July*, 1 – 10.

Michelini, M., & Stefanel, A. (2010). High school students face QM basic concepts. *New Trends in Science and Technology Education*, *1*, 308 – 322.

Ministry of Education Malaysia. (2012). Malaysia Education Blueprint 2013 - 2025. In *Kementerian Pelajaran Malaysia*. https://doi.org/10.1016/j.tate.2010.08.007

Mousa, R. (2016). *Mathematics Teachers' Readiness and Attitudes Toward Implementing Integrated Stem Education in Saudi Arabia: a Mixed Methods Study* (Issue December). https://doi.org/10.1016/j.jpowsour.2008.09.008

Müller, R., & Wiesner, H. (2002). Teaching quantum mechanics on an introductory level. *American Journal of Physics*, *70*(3), 200 – 209. https://doi.org/10.1119/1.1435346

Park, M., Dimitrov, D. M., Patterson, L. G., & Park, D. (2016). Early childhood teachers ' beliefs about readiness for teaching science , technology , engineering , and mathematics. *Journal of Early Childhood Research*, 1 – 17. https://doi.org/10.1177/1476718X15614040

Park, Y. S., Konge, L., & Artino, A. R. (2019). The Positivism Paradigm of Research. *Academic Medicine*, 1. https://doi.org/10.1097/acm.0000000000003093

Planinic, M., Boone, W. J., Susac, A., & Ivanjek, L. (2019). Rasch analysis in physics education research: Why measurement matters. *Physical Review Physics Education Research*, *15*(2), 20111. https://doi.org/10.1103/PhysRevPhysEducRes.15.020111

Pospiech, G. (2019). Pre-Service Teacher ' s Views on the use of Metaphors for Describing the Concepts of Uncertainty and Entanglement in Teaching Quantum Physics. *International Journal of Physics and Chemistry Education*, *11*(1), 1 – 5.

Rainer, M., & Wiesner, H. (1999). Students' Conceptions of Quantum Physics. *National Association for Research in Science Teaching March, 1999*, *13*(1), 20 – 22. https://doi.org/10.1103/PhysRevPhysEducRes.13.010109

Ramli, A. A., Ibrahim, N. H., Surif, J., Bunyamin, M. A. H., Jamaluddin, R., & Abdullah, N. (2017). Teachers' readiness in teaching STEM education. *Man in India*, *97*(13), 343 – 350.

Ramli, N. F., & Talib, O. (2017). Can Education Institution Implement STEM? From Malaysian Teachers' View. *International Journal of Academic Research in Business and Social Sciences*, *7*(3), 721 – 732. https://doi.org/10.6007/ijarbss/v7-i6/3032

Rohaida, M. (2017). Tahap pengetahuan, pemahaman dan kesediaan guru bahasa Melayu dalam melaksanakan kajian pengajaran (Level of Knowledge, Understanding and Readiness Malay Language Teachers to Implementing Lesson Study). *Jurnal Pendidikan Bahasa Melayu*, *7*(2), 30 – 40. https://doi.org/10.1080/10635150600755453

Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, *57*(1), 1 – 23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Stadermann, H. K. E., & Goedhart, M. J. (2020). Secondary school students' views of nature of science in quantum physics. *International Journal of Science Education*, *42*(6), 997 – 1016. https://doi.org/10.1080/09500693.2020.1745926

Stadermann, H. K. E., Van Den Berg, E., & Goedhart, M. J. (2019). Analysis of secondary school quantum physics curricula of 15 different countries: Different perspectives on a challenging topic. *Physical Review Physics Education Research*, *15*(1), 1 – 25. https://doi.org/10.1103/PhysRevPhysEducRes.15.010130

Sumintono, B., & Widhiarso, W. (2015). *Aplikasi Pemodelan Rasch pada Assessment Pendidikan* (Issue September). Penerbit Trim Komunikata.

Wearmouth, J., Edwards, G., & Richmond, R. (2000). Teachers' professional development to support inclusive practices. *Journal of In-Service Education*, *26*(1), 49 – 61. https://doi.org/10.1080/13674580000200111

Weiner, B. J. (2009). A theory of organizational readiness for change. *Implementation Science*, *4*(1), 1 – 9. https://doi.org/10.1186/1748-5908-4-67

Widodo, A. (2017). Teacher Pedagogical Content Knowledge (PCK) and Students' Reasoning and Wellbeing. *Journal of Physics: Conference Series*, *812*(012119), 1 – 7. https://doi.org/10.1088/1742-6596/755/1/011001

Wook Cheong, Y., & Song, J. (2014). Different Levels of the Meaning of Wave-Particle Duality and a Suspensive Perspective on the Interpretation of Quantum Theory. *Science and Education*, *23*(5), 1011 – 1030. https://doi.org/10.1007/s11191-013-9633-2

Yan Piaw, C. (2020). *Mastering Research Statistics* (Second Edi). McGraw Hill Education (Malaysia).