Designing Optical Spreadsheets-Technological Pedagogical Content Knowledge Simulation (S-TPACK): A Case Study of Pre-Service Teachers Course

M. Anas THOHIR
Yogyakarta State University, INDONESIA
m.anas2016@student.uny.ac.id

JUMADI
Yogyakarta State University, INDONESIA
jumadi@uny.ac.id

WARSONO
Yogyakarta State University, INDONESIA
warsono@uny.ac.id

ABSTRACT
In the 21st century, the competence of instructional technological design is important for pre-service physics teachers. This case study described the pre-service physics teachers' design of optical spreadsheet simulation and evaluated teaching and learning the task in the classroom. The case study chose three of thirty pre-service teacher's course at Yogyakarta State University. A bonded system explored basic knowledge and integration ability of the pre-service teacher. In addition, peers assessed the simulated performance of pre-service teachers by using Spreadsheet-Technological Pedagogical Content Knowledge (S-TPACK). Pre-service teachers transform the topic into a unique spreadsheet simulation. One of them designed with high complexity, but the others are not. However, they demonstrated different the intensity and integrity of teaching strategies, the depth of optical topics, and interactive spreadsheets. In the future, the design of instructional technology will need to pay attention to the basic knowledge of TPACK, problem-solving, and self-efficacy.

INTRODUCTION
Essential pre-service physics teachers' qualification is how to integrate technology into models of learning in instruction for the 21st-century. This integration should make difficult physics content in a meaningful learning TPACK integration model (Levinz & Klieger, 2012). Technology is an influential cognitive device to facilitate both teachers' instructional practice, student process learning, and improvement of students' achievements (Gao & Mager, 2013; Srisawasdi, 2012). Although pre-service physics teachers have received various physical content, they will not automatically be able to integrate technology in learning (Wu, Hu, Gu, & Lim, 2016). Design-based learning (DBL) has led to an increase of TPACK-in-action knowledge, attitude, and skills (Baran & Uygun, 2016).

The limitations of designing instructional technology are using hard-to-learn software or materials, requiring lots of complex scripts, costly tools. Spreadsheets are one of the many flexible application software to make easy physics learning. Spreadsheet support for modelling and analysing variables in various physics learning contexts (Margaret L. Niess, van Zee, & Gillow-Wiles, 2010). This software allows simulating a phenomenon of responsive physics processes such as magnification, rotation, and motion. Pre-service physics teachers only need to know the main principles in making algorithms that will be created in the design of media in the learning context of physics. But utilising of a spreadsheet may not necessarily be an easy task to calculate algorithms in a physical context (Baker, 2011).

This study presents how pre-service physics teachers designed optic simulation and how they use it to show TPACK integration in the practice. Before presenting the designing pre service teacher's spreadsheet, this work explains the transformative TPACK paradigm, promote S-TPACK assessment, and the method of this work. Using spreadsheets in optic simulation help student to make it easier and to reduce the cost of infrastructure. A famous designation is "optics is what physicists do in a dark room"(Thekaekara, 1964). This situation is more difficult than opening the laptop and spreadsheet. However, a teacher needs to "know better than his students" (Michael Neubrand, Nanette Seago, 2009).

Spreadsheet design in transformative TPACK paradigm

Shulman had founded the concept of integration pedagogical knowledge (PK) and content knowledge (CK) as pedagogical content knowledge (PCK) model (Shulman, 1986). It was developed by Mishra and Koehler to support technological knowledge (TK) integration into PCK. This integration was called by technological pedagogical content knowledge (TPACK) framework (Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007). However, Angeli (2005) has another view that the design of instructional technology requires a transformation of the subject matter and pedagogy appropriate to the selection of technologies that match the characteristics of students. Transformation of TPACK means that component of TPACK is not summative, but they are the new synthesis (Graham, 2011). However, pre-service teachers need to adapt to the characteristics of students. But in the simulation, they are playing a role like in a classroom environment. Characteristics of student performance are determined based on an approximate optical topic designed to be optically spreadsheet tsimulation. Figure 1. shows how they transform optical material into a spreadsheet simulating.

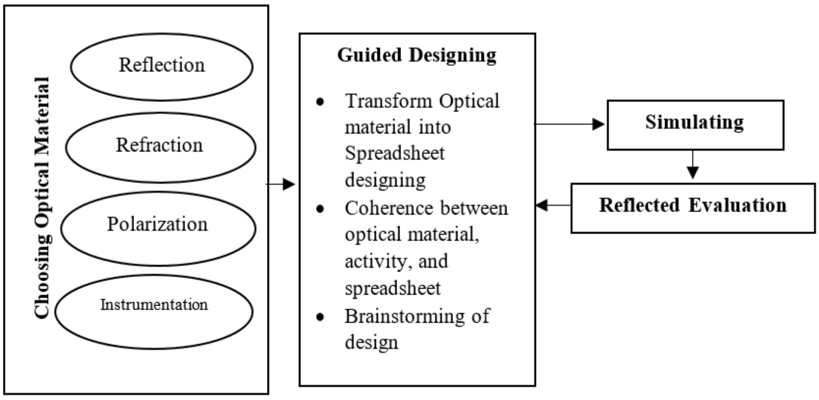

Figure 1 Transforming optical material into spreadsheet simulating

Design-based learning helps pre-service teachers connect theory and practice (Baran & Uygun, 2016) and is also a challenge that reflects the real world (Koehler & Mishra, 2005). While pre-service teachers transform optical topics into spreadsheets, they have analysed possible theories to be designed and then applied. The main key to design is the coherence between material, artefact and activity (Koehler & Mishra, 2005). Artefacts show a number of processes that have been done that, hold many stories of activities.

Pre-service teachers are necessary to have a basic knowledge of the components of technology, content, and pedagogy (Koehler & Mishra, 2005) in DLB-TPACK. However, when they design artefacts simulation, they need to define and solve problems (Baran & Uygun, 2016), creative process design (Voogt, Fisser, Tondeur, & Braak, 2016), and self-efficacy (Gao & Mager, 2013; López-Vargas, Duarte-Suárez, & Ibáñez-Ibáñez, 2017; Tondeur, Scherer, Siddiq, & Baran, 2017; Yerdelen-Damar, Boz, & Aydın-Günbatar, 2017a). That ability will be very helpful when combining the basic components of TPACK.

Spreadsheet Technological Pedagogical Content Knowledge (S-TPACK) Assessment

TPACK assessment follows TPACK framework component; PK, CK, TK, PCK, TCK (technological content knowledge), TPK (technological pedagogical knowledge), and TPACK component (Baran & Uygun, 2016; Mouza, Karchmer-Klein, Nandakumar, Ozden, & Hu, 2014; Schmidt & Baran, 2009; Ward, 2013). Koehler et al (2014) reviewed that performance assessment directly evaluates participants' TPACK in authentic teaching tasks. Stoilescu (2015) used diagrams to illustrate key aspects of technology integration into classroom teaching and learning. He uses the estimates indicate the size of knowledge of each component of the diagram TPACK (Stoilescu, 2015). This study uses spreadsheets (S-TPACK) to give the teacher's estimation of expertise in classroom technology integration.

S-TPACK is a tool to assess TPACK component of a pre-service teacher that peer assessment based. The peer assessment of simulation is useful for teachers applying TPACK integration. There are two peer ratings that can increase TPACK. First, the open opinion of the peers helps complement qualitative data (Jang & Chang, 2016) as reflecting pre-service teaching and learning. Second, peer rating of peers is to know TPACK component integration. S-TPACK shows how the pre-service teacher has fulfilled the integration of each TPACK component during teaching in classroom learning. S-TPACK is Microsoft® Office Excel software 2016 used to design educational technology, media and to know the S-TPACK intensity and integration. Figure 2 shows how to evaluate TPACK teacher with spreadsheet teacher. The control of TPACK intensity is used to determine the radius of the knowledge both PK, CK, and TK. The integration control TPACK is used to determine the size of PCK, TPK, TCK, and TPACK integration.

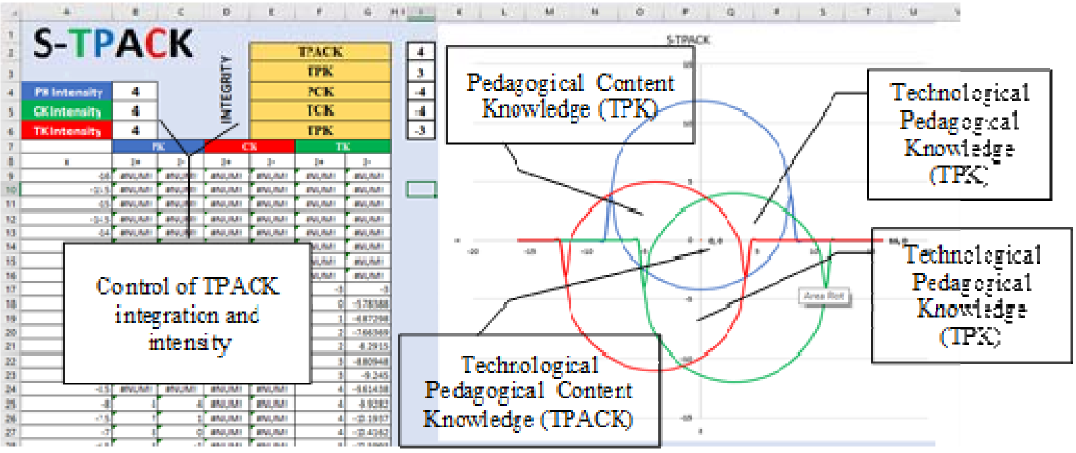

Figure 2 S-TPACK intensity and integration, the control of TPACK intensity and integration

Optics Knowledge

The subtopics in optics are the behaviour of light, reflection, refraction, lenses, and optical instruments (Thekaekara, 1964). Light present to a mirror will be reflected and to a lens will be refracted. The images of reflection and refraction have certain patterns when the surface is continuous. This is what will format the optical geometry. Birefringence anisotropy is one of the important topics to be studied because, in addition to looking for a refractive index, it is also used in some technologies such as harmonic crystal generation, phase wave conjugate, image processing, computer optics, and optical data storage (Matlin & McGee, 1997).

Previous research has shown that most teachers use or create demonstration tools to simulate optical topics. Creative ways are used in optical learning such as cone demonstrations in water (Etkina, Planinši, Vollmer, Etkina, & Vollmer, 2013), diffraction spectrometer (Polak et al., 2014), control system for optics setup (Frank L.H. Wolfs, 2015), spectrometer and computation (Matlin & McGee, 1997), online learning (Hoeling, 2012), and computer-based tutorial on the photoelectric effect (Steinberg, Oberem, & McDermott, 1996). In this study, spreadsheets were used to be a simulated medium in learning, but they designed what they had understood in previous meetings about TPACK.

The pre-service teacher needs special skill to simulate the topics because the optical material is not the right material to memories. However pre-service teachers will teach these topics to students. Learning strategies like Real Time Physics (RTP), Interactive Lecture Demonstrations (ILDs), and Active Learning in Optics and Photonics (ALOP) are quite effective in optical learning (Sokoloff, 2016). Most teachers use or make demonstration tools to simulate optics such as demonstration of conical beams in water (Etkina et al., 2013), make diffraction spectrometer (Polak et al., 2014), some ware using a spectrometer then calculated by computing (Matlin & McGee, 1997), using online demonstration (Hoeling, 2012), and computer-based tutorials on the photoelectric effect (Steinberg et al., 1996), Even a rather complex make the control tool direction, control system for optics setup (Frank L.H. Wolfs, 2015). In this study, the pre-service teacher focuses on the task of designing the optical simulation and simulating it. The study aimed to describe (a) how the pre-service teacher designs the simulation by transforming the optical topic into S-TPACK and (b) to evaluate pre-service teachers S-TPACK simulation.

THE STUDY

The bounded system in this "case study" processes task designing and perform optic simulating in a classroom setting. The case study reveals the complexity of TPACK development (Baran & Uygun, 2016). Multiform data, simulation design results and assessment results from peers, was collected for the development of in-depth understanding (Creswell, 2012). In detail, TPACK framework can be conducted by exploring the experienced pre-service integrating (Stoilescu, 2015) spreadsheet.

Participants

In this case, participants were three pre-service teachers (two male and one female). Their names (pseudonyms) are Amin, Chika, and Budi. They came from three different islands of Indonesia. They were chosen from 30 students of the physics teacher department at Yogyakarta State University. They have been attending optics course for 14 weeks in 6th semester of the academic year 2016. They aged 23 to 26 years old. All of them have followed basic computer program like Word, PowerPoint, and Excel.

Course Program

The first-course program, the instructor introduced participants about the optical topics and the instructor assigned project task from four topics. They draw one of four topics in small paper rolls. The schedule of discussion deal is 6 weeks for the designing of spreadsheet simulation under the guidance of the instructor, 4 weeks to simulate what they have done, 3 weeks to do the simulation improvement and 2 weeks to revise. The second, dividing the task, participants are encouraged to discuss the potential effects of TPACK component critically. In the discussion, also critically discussed five important competencies of transformative; (1) topic identification, (2) powerful pedagogy identification, (3) tactic teaching identification, (4) tools selecting, and (5) computer activity infusion to classroom activity (Angeli & Valanides, 2013). They can consult in the autonomy task and the instructor guided the process of design. The last of courses, pre-service teacher simulate what they have designed. They shared the results of simulation design spreads before. Each pre-service teacher presents the design result. The assignment of other pre-service teachers is as a student and observer to give inserts to the presenter after the simulation. While the instructor becomes a mediator and evaluator at the end of learning.

Data collection

Two participant activities were conducted to explore the case in this study. First, design activities reveal their efforts in passing the transformation steps. The product from the design illustrates how spreadsheet represents the selected optical topic and teaching strategy. Second, the simulation activity describes the coherence between optical material, activity, and spreadsheets simulation. The pre-service teacher that plays a role as a student provided an assessment using S-TPACK intensity and integration. The assessment items are five points Likert Scale, namely, (1) strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree and (5) strongly agree. S-TPACK contains instrument Schmidt & Baran (2009) to form the integration and intensity of three circles PK, CK, and TK which by substituting "I" to "My teacher". However, this data has been confirmed through unstructured interviews.

Data analysis

In design activities, pre-service teachers transform the topic into a simulation spreadsheet based on TPACK competency. Pre-service teacher activities were extracted through interviews to know each step of transformation, the source of ideas, and products. The artefacts of design explanation have revealed TPACK integration before they simulate it. At the time of the simulation, peer and instructor's suggestions were analysed to uncover spreadsheet simulation improvements.

FINDINGS

Case I: Amin's spreadsheet simulation design and Spreadsheet simulation activity

Amin is a 26-year-old male. He was born in the metropolitan city of Surabaya, where the use of technology has been common in schools. Moreover, he used to take a computer graphics course. He often presents tasks with technologies such as slides and animations. Nevertheless, he felt the need to gain experience in designing technology to teach physics.

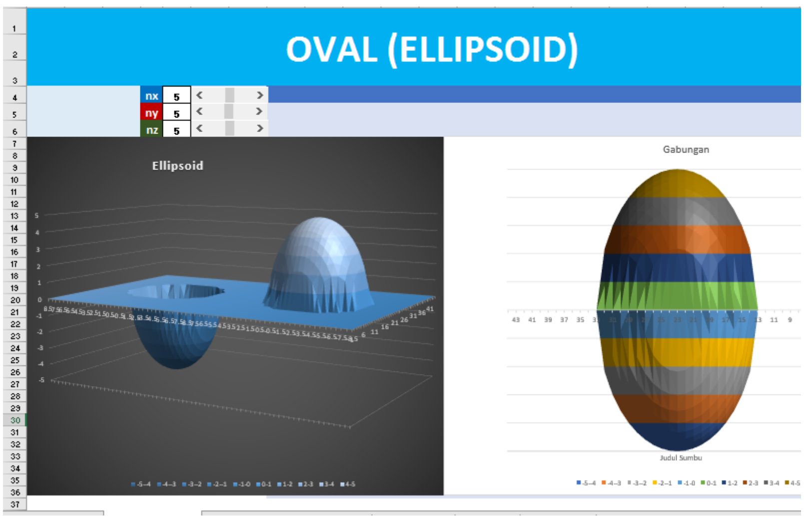

Figure 3 Amin's birefringence anisotropic spreadsheet simulation design

Amin got a refraction topic in a lottery roll. The topic was then selected based on abstraction and students' learning difficulties. His identification was based on reference books, websites, and YouTube videos. The challenge was how to transform the abstract topic into technology. Figure 3 shows Amin's birefringence anisotropic spreadsheet simulation design. Amin commented on the birefringence anisotropic spreadsheet simulation design as follows.

> "At first, I was confused about choosing a topic because some topics are too simple and some others are very difficult. But if I choose a simple topic, the use of technology will only complicate the preparation of teaching. Therefore, I chose a topic with a high difficulty level, that is the birefringence phenomenon. This most important topic is to visualise the geometry of the refractive index formed from the ordinary and extraordinary. I am trying to design a spreadsheet that can imagine ordinary and extraordinary refractive in the form of an ellipsoid".

For powerful pedagogy identification competence, Amin chose a direct interaction model. At first, he would show the problem of ordinary and extraordinary refraction on a crystal, then he went into the material with the help of a spreadsheet as a help explain it. Furthermore, in the teaching identification tactics, he selected to display some birefringence phenomenon. The tool used was a laptop and LCD projector to display birefringence phenomenon. Nevertheless, the choice of direct interaction model would make the student activity decreases. The use of birefringence anisotropic spreadsheet simulation serve as a visual medium, but low student activity.

Amin chose using the demonstration material. He seemed to dominate the class in half an hour's time. The material presented more reveals the role of electromagnetic waves forming ordinary and extraordinary waves. The ellipse equation was also derived from Maxwell's equation by using slides. Pre-service teacher students were given the chance to try the birefringence anisotropic, Amin's simulation design at minute 36 minutes. At the end, he provided the subject of the spreadsheet file to the pre-service teacher in computer activity. The pre-service teacher-student is given an opportunity to comment. Budi commented on the look of the Amin as follow.

> "I am more interested in oval-shaped charts that are formed from the spreadsheet. The oval can be enlarged and rotated. Also, the real data from the birefringence anisotropic equation can form an ellipse, but this is a math content. For simulation activities less accommodating students, I suggest better students are given the opportunity to look for anisotropic birefringence form. Students will autonomously determine the shape of the graph when it is biaxial and uniaxial".

Pre-service teachers need to pay attention to technology for meaningful learning. Difficult and abstract topics meet for transformative into technology, but meaningful learning perfects the importance of pedagogical learning (C. S. Chai, Tan, Deng, & Koh, 2016). However, Amin did not display a simulation spreadsheet in a contextual form. He drew more attention to spreadsheet simulation of anisotropic birefringence than a classroom activity.

S-TPACK intensity indicates that Amin has TK strong agree, CK agree, and PK disagree. The great value of TK gets from a complicated and interesting simulation. He has a high enough design flair with an attractive garnish. He also cuts the ellipsoid into two parts, top and bottom. In addition, the ellipsoid can be shaped like a pumpkin. While the small PK is more affected by the identification of pedagogy that is not strong. Figure 4 shows S-TPACK intensity and integrity of Amin's TPACK. The intensity of S-TPACK indicates that Amin has a well-executed TK and CK agreement, but the PK does not agree. For S-TPACK integrated, Amin's birefringence anisotropic simulation activity shows great integrity in TCK, while PCK and TPK obtain small results. Small PK and poor integrity make PCK, and TPK gets a little result. Inadequate pedagogy identification, making PCK and TPK components too small. As for TPACK integrity obtained a not so great value, the contribution is still in kindergarten and PK intensity and integrity.

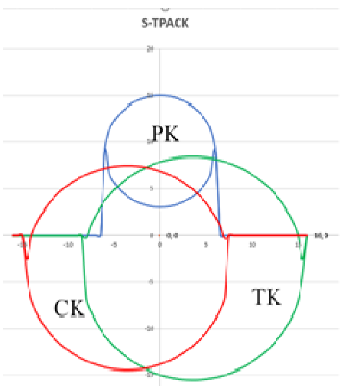

Figure 4 Amin's S-TPACK intensity and Integrity

Case II: Chika's Spreadsheet simulation design and Spreadsheet simulation activity
Chika is a 23-year-old woman. He was born in the village of Lampung, a small town in Chika was a 23-year-old woman. He was born in the village of Lampung, a small town in the village of Sumatra island. Nevertheless, since childhood, he has been schooled in the city. He also often presents tasks with slides. He got a high academic achievement index, but low computer skill.

When picking up the lottery, he got the reflection topic. To find this topic in accordance with abstract and difficult requirements, it does require experience in teaching. Therefore, he combines two topics at once, reflection and refraction to describe the absorption. The use of technology on this topic requires a simple design, but many modifications of basic spreadsheet design techniques. Chica argued

> "I combine Snellius equations, graphs, and power pivots on the dashboard menu. This technique is easy, it just requires manipulating the angle of Snellius's law. Next, I make the equation at the angle of bias and the angle comes with the variable angle comes."

To show the reflection and refraction of light simulation design to powerful, Chika requires pedagogy techniques and tactics. Figure 5 shows Chika's spreadsheet simulation by selecting reflection material, refraction, and absorption. He has determined that the simulation is suitable for cooperative model learning. The reason, he can divide the students into groups of refraction, reflection, and absorption. Each group shares their experiences according to their expertise. He still needs LCD projector and laptop in each group.

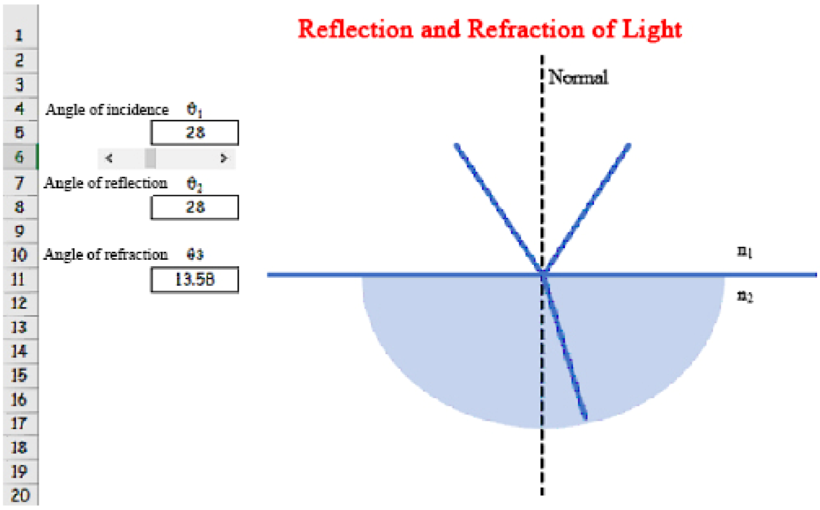

Figure 5 Chika's reflection and refraction of light spreadsheet simulation

Learning activities are dominated by discussions. Preliminary activities (first 15 minutes) led to direct instruction and group discussions. Students of pre-service teachers try spreadsheet of reflecting and refracting on the simulation of light. Finally, the pre-service teacher commented on Chika's simulation. Budi stated about the choice of reflection and refraction of light spreadsheet simulation.

> "We have already discussed how the coming angle and reflection angle produce the same number, but the incident angles and bias angles differ in water. In my opinion, this simulation is interesting, I hope to be coloured on the spreadsheet to make it more interesting. The calculations of Snellius's law need to be included as a more detailed explanation."

Results by stuffing S-TPACK intensity indicates that Chika has TK and agree CK and strong agree with PK. The value of the balance between the three caused by learning is interesting. A spreadsheet technology that can be used separately for one topic, but can be used for other topics. PK has a most interesting effect on group classes and more student engagement. So also in CK, he got a high score because the optical material was easily understood by pre-service teacher students. But TK gets a small score, this is due to the level of difficulty and appearance that is less interesting.

For S-TPACK integrity, Chika's reflection and refraction of light simulation activity demonstrate great integrity in TCK, PCK, and TPK. Figure 6 shows the large TPACK integration on PCK, while TCK and TPK get the same value. Nonetheless, simulation of Chika may indicate that the most important element of the pre-service teacher is PK and CK, while TK supporting role.

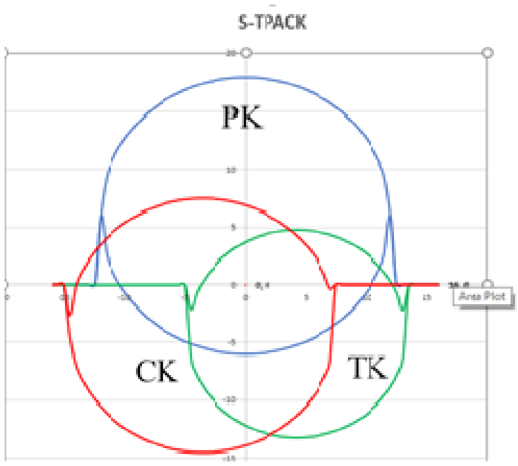

Figure 6 Amin’s S-TPACK intensity and Integrity

Case III: Budis’ spreadsheet simulation design and Spreadsheet simulation activity

Budi is a 25-year-old male. He was born in Lombok, close to the island of Bali. He is the son of a lecturer in Java. His communication skills with good lecture language. In addition, he also attended the physics Olympics in Lombok. When presenting lessons often use their own words with contextual topics. At the time of taking the lottery, he acquired the topic of polarisation. This topic is real but the symptoms that arise. To be able to design a spreadsheet on this topic it is necessary to understand the polarisation equations and Polaroid data as an example. At the time of polarised light, interference will arise. Therefore, Budi chose the interference between two waves, the waves in optical linear and nonlinear wave in the first order. Budi claimed

> “Once I get the polarisation material, I am reminded of the interaction between light and Polaroid, where the light will be polarised with superposition. I am looking for ideas to design topic polarisation into the spreadsheet simulation. The result is superposition two waves, e.g. linear range and nonlinear wave simulation. Actually, the principle is the same as the damped and muffled vibration.”

Budi designs a spreadsheet with a problem-based learning (PBL), he believed that by selecting it students could manipulate based on the given problem. The result of the identification, he proposed tips for interested students, one sheet of the spreadsheet was used to write problem formulas, problem-solving plans, problem testing, and answer questions. In problem testing, students can use screenshots inserted on the first sheet to draw the superposition of the two waves. The second sheet used interactive spreadsheet simulation.

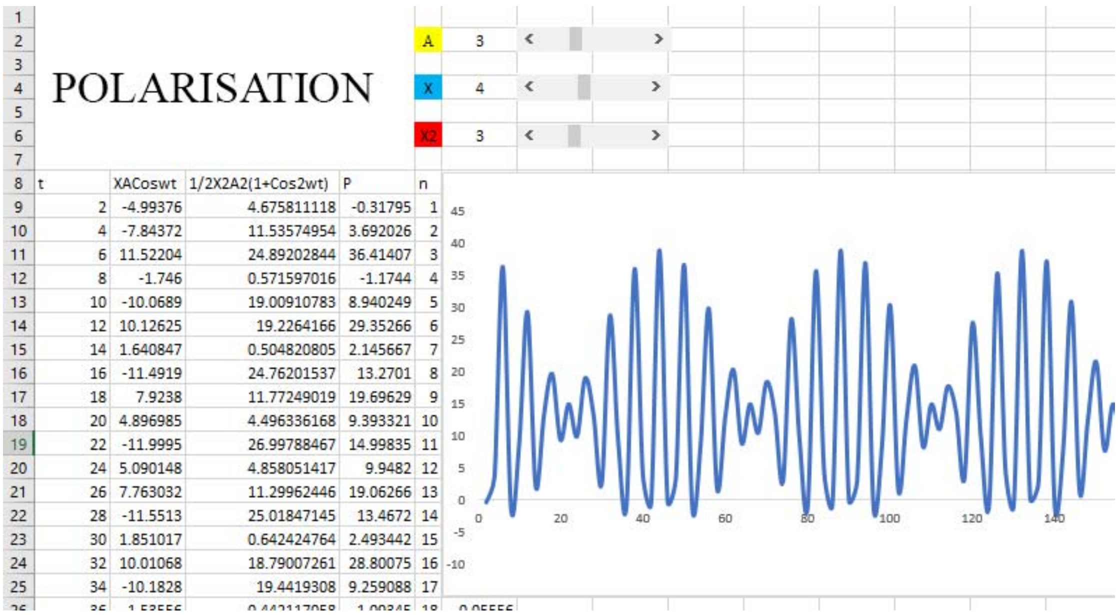

Figure 7 Budi’s polarisation spreadsheet simulation design

Spreadsheet simulation activity was used for core activities, whereas in early learning activities, he invited pre-preservice teacher students to observe the light beam passed on a polarisation through a YouTube video. He divided the discussion group to solve the problems that had been prepared beforehand. Pre-service teacher student tried to manipulate Budi's polarisation simulation design. Figure 7. shows one of Budi's polarisation simulation design. At the end of the lesson, the pre-service teacher-student gave a comment about Budi's simulation. Chika responded to Budi.

> "You modelled the problem-solving activity very well, but we have not got the polarisation material that is not deep yet. We just manipulate the simulation spreadsheet equation. We advise to add depth of material and also technological sophistication."

For S-TPACK, pre-service teacher-student intensity assessed the performance of Budi with disagree TK and disagree CK, and strong agree on PK. The value of problem-solving presentations was the best, polarisation topics and spreadsheet technologies that can be used separately for one topic but can be used for other topics. PK has a more interesting effect on group classes and more student engagement. Likewise, in CK, he got a high score because it represents material that can hit students. But TK got a small score even though still in the agree on status, this is due to the level of difficulty and appearance that was less interesting.

Budi's design shown great integrity on TCK but is small for PCK and TPK as Figure 8. The simulation activity was interesting, although the content knowledge was not deep to explore all polarization topic. He had confidence in pedagogical knowledge. He was able to organize classes for active, motivating, and steering thinking. However, he used technology as a support activity in the problem-solving test.

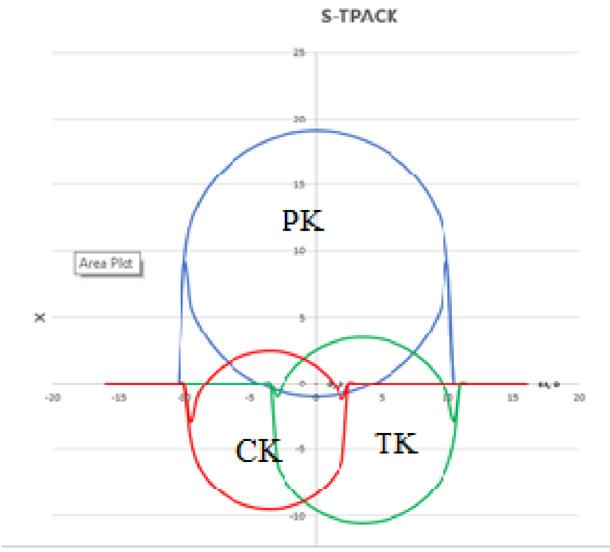

Figure 8 Budi's S-TPACK intensity and Integrity

DISCUSSION

Judgment of pre-service teacher design the simulation

This study served to describe the complexity of pre-service physics teachers in designing optical simulation with a spreadsheet. In choosing the optical material stage of design, they must define the target, the scope of content, and select the tools (Chou & Tsai, 2002; Strijbos, Martens, & Jochems, 2004). Although they have chosen the topic in a random way, they still required basic knowledge (PK, CK and TK) as a requirement for the instructional designer. PK helps pre-service teachers to choose strategies such as direct interaction, collaborative learning, and problem-based learning, CK organizes the structure of lesson content, and TK allows them to design in accordance with the structure of lesson content. This basic knowledge indicates the pre-service teacher's readiness in technology integration (Baran & Uygun, 2016; Copriady, 2014; Howard, Chan, & Caputi, 2015). The difference of pre-service teachers background will make intensity difference of S-TPACK, especially in basic knowledge. Previous research has shown that there is a relationship between TPACK with the teacher background (Lee & Tsai, 2010; M. L. Niess, 2005; Stoilescu, 2015). Amin has a high school background that uses technology more than Chika and Budi. The results show that Amin has the highest technological knowledge. Nevertheless, he earned the least value for pedagogical knowledge. Previous research has shown that pre-service teachers need practice guided theory, readiness to design, technology expertise, and continue learning of TPACK (Baran & Uygun, 2016). For optimization, the design participants must pay attention to the contradictions and tensions of each factor of the basic knowledge (Koehler & Mishra, 2005). The basic knowledge is as a knowledge capital to integrate into TPACK as well as the identified impacts (Celik, Sahin, & Akturk, 2014; C. S. . Chai, Ling Koh, Tsai, & Lee Wee Tan, 2011).

Transformative competence is a process of transforming topics into technology through powerful pedagogy (Angeli & Valanides, 2005). The pre-service teacher must conduct each step of transformative competence (Angeli & Valanides, 2013). It is not easy for a pre-service teacher to determine each of Angeli & Valanides five steps. Amin got the low competence of pedagogy identification, it influenced on the competence of tactic teaching identification. However, he got a high ability in the topic transformation into spreadsheet design. The case studies of three pre-service teachers shown the level of the integrated transformation of TPACK. Niess (2011) has demonstrated levels in developing TPACK with five level, (1) recognizing, (2) accepting, (3) adopting, (4) exploring and (5) advancing. However, the pre-service physics teacher reached the level of advancing when they design spreadsheet simulation. However, all of them reached the spreadsheet adaptation level in the design with the optical topic. In fact, two of the three pre-service teachers have achieved exploring because they consistently exploited the spreadsheet and one achieved advancing because he has decided to integrate the spreadsheet as the next development topic (Margaret L Niess, 2013).

The finding of this study that pre-service teacher can develop TPACK competence when pre-service teacher necessary pay attention basic knowledge, transformative process, and affective value of pre-service teacher. Brinkerhoff (2005) argue that the five main categories prevent integration technology; resources, administration support, experience, and attitudinal factor. However, Amin, Chika, and Budi have made decisions, doing problem-solving, and generate confidence. Dominantly, they have done the problem-solving process, because the experience is often associated with problem-solving (Docktor et al., 2016; Teodorescu, Bennhold, Feldman, & Medsker, 2013). Hill (1998) argued that the design process is seen as creative, dynamic and iterative processes. Problem-solving is needed to be shaped by existing sources and tools and adapts to situations specifically and changes (McCormick, Murphy, & Hennessy, 1994). In the TPACK design, the pre-service teacher has performed self-regulated learning. In a similar view, Voogt et al. (2016) presents that there is a TPACK relationship with self-regulated learning. Self-efficacy is often referred to as attitude factor in the integration of technology (Brinkerhoff, 2005; Cullen & Greene, 2011; López-Vargas et al., 2017). In evidence, besides self-efficacy, experience, and attitude toward technology also direct influence TPACK integration (Yerdelen-Damar, Boz, & Aydın-Günbatar, 2017b).

TPACK assessment spreadsheet simulation activity

Implementation of the spreadsheet design had led to assess optical simulation action because pre-service physics teacher needs TPACK comprehension competence to influence teaching simulation (Srisawasdi, 2012). Assessment of TPACK-in-action used questionnaire S-TPACK. This is not for self-assessment, but the pre-service teacher is detected through peer assessement which is done to assess the pre-service performance of teacher in action. Willermark (2017) revealed that there is a gap between self-reporting and performance in action where explored performance is more flow oprasional TPACK. Furthermore, Stoilescu (2015) intuitively used an adapted graph to depict teacher TPACK framework. However, he did not mention how to draw the graph. S-TPACK can be an alternative in describing the TPACK framework of teacher performance in the classroom. The result of the student assessment can show how much the main component of PK, CK, and PK, while the third intersection can be seen from S-TPACK integrity which shows PCK, TCK, and TPK. In addition, S-TPACK intensity and integrity are also very useful in analyzing the competence of pre-service after learning. Limitations of S-TPACK can not be numerically determined TPACK integrity. The area of PCK, TPK, TCK, and TPACK is not calculated. However, the extent of the intersection of PK, CK, and TK can be estimated from the spreadsheet graph.

Case study of the pre-service teachers design the simulation can be seen from three types, (1) Strong topic transformation into spreadsheet but weak against pedagogy, causing values PK, PK, and PK are small, (2) Optical topic transformation of balanced pedagogy and spreadsheet leads to powerful instruction, and (3) Topics identification do not represent essential material, while the correct selection of pedagogical learning causes small TPK and PACK. A powerful learning is achieved at the maximum when there is a balance between TK, PK, and CK. An interesting case is that although TK is a small value, learning remains good. Thus, the main competence of a teacher is optical material knowledge and active meaningful learning. Meanwhile, TK is a booster to PK and CK.

CONCLUSIONS

This case study has three implications in design and spreadsheet simulation. The first, the study recommends using spreadsheets for easy, cheap and flexible purposes in designing physics topics. Three pre-service teachers have proven that they have designed different optical topics with different forms and interactive. Second, design activities require knowledge, skills, and attitudes. (1) Basic knowledge is required as the main capital in the design, that is knowledge of appropriate physics topic, technological expertise, and pedagogical knowledge. (2) Creativity design helps in integrating technological skills into the knowledge of physics topics and pedagogical knowledge at once. Design creativity requires problem-solving and decision-making skills in brainstorming conditions. Strong imagination also helps to get a unique design. (3) Self-efficacy, self-believe, or confidence is required to assure the ability to achieve an optimal design. Finally, simulation activities can be evaluated using S-TPACK and peer comments. S-TPACK helps pre-service and instructor to know the intensity of PK, CK, and TK from the diagram. In addition, S-TPACK can show PCK, TCK, and PTK based on PK, CK, and TK diagram intersections.

The limitation of this study, the authors can not record the specifics of the activities during the pre-service teacher independent design. Activity recording is useful for knowing personal self-regulated learning during the project design. Cuthbert (1995) proposed a model of project planning and self-regulated learning to detailed the effectiveness of self-management. Self-regulated learning strategy of a pre-service teacher can be seen from action or process directly either information or skill involving agent, goals, and perception of the pre-service teacher (Zimmerman, 1989). Pre-service teachers develop self-regulated learning during activity design problems (Cuthbert, 1995). In addition, S-TPACK integration can not quantitatively determine the integration between PK, CK, and TK. The S-TPACK results can only show descriptively the extent of the PK, CK, and TK cross section intersection plots.

For future research, the authors propose to develop self-regulated learning rubric during project design and S-TPACK with quantitative values on the intersection of PK, CK, and TK in the graph. Pre-service teachers use resources to reflect on design projects and instructors can guide based on their efforts in design. Moreover, S-TPACK developed a web-based spreadsheet with higher precision accuracy.

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REFERENCES

Angeli, C. (2005). Transforming a teacher education method course through technology: Effects on preservice teachers' technology competency. *Computers and Education*, *45*(4), 383–398. http://doi.org/10.1016/j.compedu.2004.06.002

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of. *Journal of Computer Assisted Learning*, 292–302. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2729.2005.00135.x/full

Angeli, C., & Valanides, N. (2013). Technology mapping: An approach for developing technological pedagogical content knowledge. *Journal of Educational Computing Research*, *48*(2), 199–221. http://doi.org/10.2190/EC.48.2.e

Baker, K. R. (2011). Solving sequencing problems in spreadsheets. *International Journal of Planning and Scheduling*, *1*(1/2), 3. http://doi.org/10.1504/IJPS.2011.044556

Baran, E., & Uygun, E. (2016). Putting technological, pedagogical, and content knowledge (TPACK) in action: An integrated TPACK-design-based learning (DBL) approach. *Australasian Journal of Educational Technology*, *32*(2), 47–64. http://doi.org/10.14742/ajet.2551

Brinkerhoff, J. (2005). Effects of a Long-Duration, Professional Development Academy on Technology Skills, Computer Self-Efficacy, and Technology Integration Beliefs and Practices. *Journal of Research on Technology in Education*, *39*(1), 22–43. http://doi.org/10.1080/15391523.2006.10782471

Celik, I., Sahin, I., & Akturk, A. O. (2014). Analysis of the Relations Among the Components of Technological Pedagogical and Content Knowledge (Tpack): a Structural Equation Model *. *Journal Educational Computing Research*, *51*(131110001), 1–22. http://doi.org/doi: http://dx.doi.org/10.2190/EC.51.1.a

Chai, C. S. ., Ling Koh, J. H. ., Tsai, C.-C. ., & Lee Wee Tan, L. . (2011). Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers and Education*, *57*(1), 1184–1193. http://doi.org/10.1016/j.compedu.2011.01.007

Chai, C. S., Tan, L., Deng, F., & Koh, J. H. L. (2016). Examining pre-service teachers' design capacities for web-based 21st century new culture of learning. *Australasian Journal of Educational Technology*, *33*(November 2016), 1–20. http://doi.org/10.14742/ajet.3013

Chou, C., & Tsai, C.-C. (2002). Developing web-based curricula: Issues and challenges. *Journal of Curriculum Studies*, *34*(6), 623–636. http://doi.org/10.1080/00220270210141909

Copriady, J. (2014). Self - Motivation as a mediator for teachers' readiness in applying ICT in teaching and learning. *Turkish Online Journal of Educational Technology*, *13*(4), 115–123. http://doi.org/10.1016/j.sbspro.2015.01.529
Creswell, J. W. (2012). *Educational Research Planning, Conducting and Evaluating Quantitative and Qualitative Research*. Boston: Pearson Education, Inc.
Cullen, T. A., & Greene, B. A. (2011). Preservice Teachers' Beliefs, Attitudes, and Motivation about Technology Integration. *Journal of Educational Computing Research*, *45*(1), 29–47. http://doi.org/10.2190/EC.45.1.b
Cuthbert, K. (1995). Project planning and the promotion of self-regulated learning: From theory to practice. *Studies in Higher Education*, *20*(3), 267–277. http://doi.org/10.1080/03075079512331381545
Docktor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., … Yang, J. (2016). Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. *Physical Review Physics Education Research*, *12*(1), 10130. http://doi.org/10.1103/PhysRevPhysEducRes.12.010130
Etkina, E., Planinši, G., Vollmer, M., Etkina, E., & Vollmer, M. (2013). A simple optics experiment to engage students in scientific inquiry Advertisement : A simple optics experiment to engage students in scientific inquiry. *American Journal of Physics*, *81*(11), 815–822. http://doi.org/10.1119/1.4822176
Frank L.H. Wolfs. (2015). A low cost mirror mount control system for optics setup. *American Journal of Physics*, *83*(2), 186–190. http://doi.org/http://dx.doi.org/10.1119/1.4895343
Gao, P., & Mager, G. M. (2013). Constructing embodied understanding of Technological Pedagogical Content Knowledge: preservice teachers' learning to teach with information technology. *International Journal of Social Media and Interactive Learning Environments*, *1*(1), 74. http://doi.org/10.1504/IJSMILE.2013.051654
Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953–1960. http://doi.org/10.1016/j.compedu.2011.04.010
Hill, A. M. (1998). Problem Solving in Real-Life Contexts: An Alternative for Design in Technology Education. *International Journal of Technology and Design Education*, *8*, 203–220. http://doi.org/10.1023/A:1008854926028
Hoeling, B. M. (2012). Interactive online optics modules for the college physics course. *American Journal of Physics*. http://doi.org/10.1119/1.3677652
Howard, S. K., Chan, A., & Caputi, P. (2015). More than beliefs: Subject areas and teachers' integration of laptops in secondary teaching. *British Journal of Educational Technology*, *46*(2), 360–369. http://doi.org/10.1111/bjet.12139
Jang, S. J., & Chang, Y. (2016). Exploring the technological pedagogical and content knowledge (TPACK) of Taiwanese university physics instructors. *Australasian Journal of Educational Technology*, *32*(1), 107–122. http://doi.org/https://doi.org/10.14742/ajet.2289
Koehler, M. J., & Mishra, P. (2005). Teachers learning technology by design. *Journal of Computing in Teacher Education*, *21*(3), 94–102. http://doi.org/10.1.1.130.7937
Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The Technological Pedagogical Content Knowledge Framework. In *Handbook of Research on Educational Communications and Technology* (pp. 101–111). New York 2014: Springer Science Business Media. http://doi.org/10.1007/978-1-4614-3185-5
Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers and Education*, *49*(3), 740–762. http://doi.org/10.1016/j.compedu.2005.11.012
Lee, M.-H., & Tsai, C.-C. (2010). Exploring teachers' perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World wide Web. *Instructional Science*, *38*(1), 1–21. http://doi.org/10.1007/s11251-008-9075-4
Levinz, A. O., & Klieger, A. (2012). How do we know they can do it? Developing TPACK in a pre-service course. *International Journal of Learning Technology*, *7*(4), 400. http://doi.org/10.1504/IJLT.2012.052213
López-Vargas, O., Duarte-Suárez, L., & Ibáñez-Ibáñez, J. (2017). Teacher's computer self-efficacy and its relationship with cognitive style and TPACK. *Improving Schools*, 136548021770426. http://doi.org/10.1177/1365480217704263
Matlin, M. D., & McGee, D. J. (1997). Photorefractive nonlinear optics in the undergraduate physics laboratory. *American Journal of Physics*, *65*(7), 622–634. http://doi.org/10.1119/1.18619
McCormick, R., Murphy, P., & Hennessy, S. (1994). Problem-solving processes in technology education: A pilot study. *International Journal of Technology and Design Education*, *4*(1), 5–34. http://doi.org/10.1007/BF01197581

Michael Neubrand, Nanette Seago, T. W. (2009). The Balance of Teacher Knowledge: Mathematics and Pedagogy. In R. Even & D. L. Ball (Eds.), *The Professional Education and Development of Teachers of Mathematics: The 15th ICMI Study* (Vol. 11, p. 277). Boston, MA: Springer US. http://doi.org/10.1007/978-0-387-09601-8

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Ozden, S. Y., & Hu, L. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education*, *71*(Advance online publication), 206–221. http://doi.org/10.1016/j.compedu.2013.09.020

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. http://doi.org/10.1016/j.tate.2005.03.006

Niess, M. L. (2011). Investigating TPACK: Knowledge Growth in Teaching with Technology. *Journal of Educational Computing Research*, *44*(3), 299–317. http://doi.org/10.2190/EC.44.3.c

Niess, M. L. (2013). Central Component Descriptors for Levels of Technological Pedagogical. *Journal Educational Computing Research*, *48*(2), 173–198. http://doi.org/10.2190/EC.48.2.d

Niess, M. L., van Zee, E. H., & Gillow-Wiles, H. (2010). Knowledge Growth in Teaching Mathematics/Science with Spreadsheets. *Journal of Digital Learning in Teacher Education*, *27*(2), 42–52. http://doi.org/10.1080/21532974.2010.10784657

Polak, R., Cua, A. J., Perez, D. J., Robertson, M. Q., Stuck, J. a., & Thomas, J. M. (2014). Low-cost student experiments in optics. *The Physics Teacher*, *52*(7), 442–443. http://doi.org/10.1119/1.4895370

Schmidt, D., & Baran, E. (2009). Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an Assessment Instrument for Preservice Teachers. *Journal of Research on Technology in Education*, *42*(2), 123–149. http://doi.org/http://dx.doi.org/10.1080/15391523.2009.10782544

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *American Education Research Association*, *15*(2), 4–14. http://doi.org/10.1017/CBO9781107415324.004

Sokoloff, D. R. (2016). Active Learning Strategies for Introductory Light and Optics. *The Physics Teacher*, *54*, 18–22. http://doi.org/10.1119/1.4937966

Srisawasdi, N. (2012). The Role of TPACK in Physics Classroom: Case Studies of Preservice Physics Teachers. *Procedia - Social and Behavioral Sciences*, *46*, 3235–3243. http://doi.org/10.1016/j.sbspro.2012.06.043

Steinberg, R., Oberem, G., & McDermott, L. C. (1996). Development of a computer-based tutorial on the photoelectric effect. *American Journal of Physics*. http://doi.org/10.1119/1.18360

Stoilescu, D. (2015). A Critical Examination of the Technological Pedagogical Content Knowledge Framework: Secondary School Mathematics Teachers Integrating Technology. *Journal of Educational Computing Research*, *52*(4), 514–547. http://doi.org/10.1177/0735633115572285

Strijbos, J. W., Martens, R. L., & Jochems, W. M. G. (2004). Designing for interaction: Six steps to designing computer-supported group-based learning. *Computers and Education*, *42*(4), 403–424. http://doi.org/10.1016/j.compedu.2003.10.004

Teodorescu, R. E., Bennhold, C., Feldman, G., & Medsker, L. (2013). New approach to analyzing physics problems: A taxonomy of introductory physics problems. *Physical Review Special Topics - Physics Education Research*, *9*(1), 1–20. http://doi.org/10.1103/PhysRevSTPER.9.010103

Thekaekara, M. P. (1964). Physics and Optics In High Schools. *The Physics Teacher*, *2*(4), 161–164. http://doi.org/10.1119/1.2350766

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2017). A comprehensive investigation of TPACK within pre-service teachers ' ICT profiles : Mind the gap ! *Australasian Journal of Educational Technology*, *33*(3), 46–60.

Voogt, J., Fisser, P., Tondeur, J., & Braak, J. van. (2016). Using Theoretical Perspectives in Developing an Understanding of TPACK. In *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators* (Second edi, p. 33). New York: Routledge. Retrieved from https://books.google.pt/books?id=v0d-CwAAQBAJ&lpg=PA177&ots=oX7gR8R6Cm&dq=Survey of Preservice Teachers' Knowledge of Teaching and Technology&pg=PA323#v=onepage&q=%22Survey of Preservice Teachers' Knowledge of Teaching and Technology%22&f=false

Ward, C. L. (2013). Teaching With Technology : Using TPACK To Understand Teaching Expertise in Online Higher Education. *Journal Educational Computing Research*, *48*(2), 153–172. http://doi.org/http://dx.doi.org/10.2190/EC.48.2.c

Willermark, S. (2017). Technological Pedagogical and Content Knowledge: A Review of Empirical Studies Published From 2011 to 2016. *Journal of Educational Computing Research*, 73563311771311. http://doi.org/10.1177/0735633117713114

Wu, B., Hu, Y., Gu, X., & Lim, C. P. (2016). Professional Development of New Higher Education Teachers with Information and Communication Technology in Shanghai: A Kirkpatrick's Evaluation Approach. *Journal of Educational Computing Research*, *54*(4), 531–562. http://doi.org/10.1177/0735633115621922

Yerdelen-Damar, S., Boz, Y., & Aydın-Günbatar, S. (2017a). Mediated Effects of Technology Competencies and Experiences on Relations among Attitudes Towards Technology Use, Technology Ownership, and Self Efficacy about Technological Pedagogical Content Knowledge. *Journal of Science Education and Technology*, *26*(4), 394–405. http://doi.org/10.1007/s10956-017-9687-z

Yerdelen-Damar, S., Boz, Y., & Aydın-Günbatar, S. (2017b). Mediated Effects of Technology Competencies and Experiences on Relations among Attitudes Towards Technology Use, Technology Ownership, and Self Efficacy about Technological Pedagogical Content Knowledge. *Journal of Science Education and Technology*, *26*(4), 394–405. http://doi.org/10.1007/s10956-017-9687-z

Zimmerman, B. (1989). A Social Cognitive View of Self -Regulated Academic Learning. *Journal of Educational PsychologyBandura&Schunk*, *81*(3), 329–339. http://doi.org/10.1037/0022-0663.81.3.329