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Research Article

Cogenerative Dialogue of Cross-Generation Educators to Improve Chemistry Teaching Quality through Technology

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Abstract

This research showed the efforts of educators in improving the quality of the chemistry classroom atmosphere through technology. Cogenerative dialogue involves a dialogue between a small number of students, teachers, and researchers. This discussion featured an ethnographic case study from the co-teaching and cogenerative dialogue involving junior lecturers, certified chemistry teachers, pre-service chemistry teachers, and students in the chemistry learning about chemical bonding, chemical elements, and laboratory introduction. This dialogue is guided by questions related to Technological Pedagogical Content Knowledge (TPACK). The SWOT analysis was used to provide an overview experienced by educators as well as TPACKing process. The use of a simple application that is a music player, video and camera can be easily used to make the class more enjoyable. Students enjoy a more comfortable classroom atmosphere with song rhythms, funny videos, and selfie activities. Constraints in mastering concepts macroscopically, sub-microscopically, and symbolically are completed by utilizing virtual/augmented reality and virtual laboratory. Cogenerative dialogue can inspire educators to try and learn the technology for teaching chemistry.

Keywords:

cogenerative dialogue, technological pedagogical content knowledge, cross-generation educators, chemistry educators, chemistry teaching quality

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Introduction

Technology may be the most influential factor that shapes the current educational landscape. Integrating technology in the classroom allows students to build 21st-century skills in technology that will be utilized in any workforce and used for the rest of their lives (Brown et al., 2018). Many schools have shown support for increasing the use of technology in the classroom by providing hardware such as tablets and computers, increasing internet connectivity, and implementing programs designed to improve computer skills for teachers and students. Internet, YouTube, Facebook, WhatsApp, and many emerging technologies have become inseparable from their daily lives (Szeto et al., 2015). Teachers are often required to be interactive and innovative by integrating technology into their teaching in line with the changing paradigm of learning in this digital era (Chen et al., 2011). Professional educators not only need to achieve pedagogical content and knowledge (Shulman, 1986, 1987) but also relevant technical knowledge to get a broader list of teaching strategies for student learning needs in the teaching process (Ottenbreit-Leftwich et al., 2010). Although teachers generally respect the use of technology for education, they often find that technology integration in learning is such a difficult challenge (Johnson et al., 2016).

Technological Pedagogical Content Knowledge (TPACK) is a framework that is widely used to understand and prepare teacher teaching knowledge related to the use of technology. TPACK emphasizes that knowledge is a subject, content and specific context in building the teacher's ability to integrate technological knowledge in classroom teaching (Szeto & Cheng, 2017). Nevertheless, the ideas of TPACK have been studied in the field of technology integration in teaching and professional development since its introduction in 2005 (Olofson et al., 2016; Tømte et al., 2015; Voogt et al., 2012). Improving the quality of chemistry learning has been pursued in various ways by educators from the planning level until evaluating its implementation through technological integration. Each of these pedagogical practices is to connect the theory of education and practice of education and a direct way to improve the quality of training and the competence of future educators to work directly with students (Obradović, 2013).

In the process, novice educators experience significant changes in their position from "students who are learning" to "educators who are educating" and facing many difficult situations. It is called "reality shock" or "transformation shock", and overcoming this difficulty is very important for professional growth (Mcglynn-stewart, 2015; Sung, 2007). Educators with several years of service experience feel more qualified to do their jobs (tasks related to planning and teaching are rated highest) than educators with less work experience (Makovec, 2018). These constraints are related to the process of transferring chemistry learning material as well as classroom and laboratory management. The difficulty is also that the implementation of technology in a school class is not as easy as imagined by beginner educators. Because teaching is the type of knowledge that is applied, field experience is the main activity in learning to teach; namely learning to teach by teaching while, as far as possible, bringing together all forms of knowledge relevant to field practice. There are beliefs about field experience that must begin with a relatively long period compared to other people who teach (Tobin, 2006). Hence, co-teaching and cogenerative dialogue become an essential method for solving teaching problems.

Coteaching and cogenerative dialogue are forms of collaboration in teaching and learning that provide dynamic structures in the classroom that help educators to improve pedagogical practices and student learning. Engaging students in a cogenerative dialogue will help educators to be involved and contribute to learning that leads to class transformation (Stith & Roth, 2008). Coteaching and cogenerative dialogue have been proposed and have influenced internationally in educational research (Tobin, 2007). Cogenerative dialogue involves a dialogue between a small number of students, teachers, and researchers. All speak, listen, and learn from each other across boundaries such as age, gender, ethnicity, and rank. Over the past decade, instructors at all levels have used cogenerative dialogue to examine issues that have an impact on teaching and learning science through local knowledge. Cogen's dialectics research pedagogy provides a structure for educators and students to identify conditions that can improve teaching and learning, to allocate individual and collective responsibilities to learning, to produce optimal learning conditions and to set research agendas based on local knowledge and experience. Cogenerative dialogue has developed into a powerful tool for teachers and students at all levels of education (Bayne & Scantlebury, 2012).

As junior lecturers involved in the teacher preparation program for the past five years, we have various problems related to the learning process, especially in Basic Chemistry lectures in the first year of the student teachers. There are still many first-year chemistry pre-service teachers who have difficulty connecting the concept of macroscopic levels with submicroscopic levels, as well as their relation to symbolic levels (Imaduddin, 2018). The chemistry learning conditions previously obtained by first-year chemistry teacher candidates indicate that there is no maturity of the chemical concept that he obtained at the previous level or chemistry at the school level. Therefore, we need to discuss with seniors especially the chemistry school-teachers in a study that involves the opportunity to use technology to improve the quality of learning in chemistry school classes especially for improving students' mastery of concepts. Students and educators have a greater responsibility to improve the quality of the learning process (Roth & Tobin, 2001). There is a shortage of classroom management skills among teachers, which is caused by some deviations in the teacher's primary education (Jasmina Delceva, 2014). This research showed the efforts of educators in improving the quality of the classroom atmosphere through technology. In this study, cogenerative dialogue and coteaching were carried out between senior teachers and junior lecturers in teaching chemistry at the high school and college level. At this stage, we involve students, teachers, pre-service teachers, and lecturers of teacher training institutions to improve the quality of school chemistry learning.

Method

Research Design

Our research on co-teaching was conducted in two high schools in Province of Jawa Tengah, Indonesia, namely SMA Negeri 15 Semarang, Semarang City, and SMA Negeri 1 Kudus, Kudus Regency, and two Universities in Semarang and Kudus, Indonesia. As part of the research, we changed roles not only as outside observers but also as active participants in teacher preparation and teaching chemistry at schools. Our research model is cogenerative dialogue, a form of participatory action research (Eldon & Levin, 1991), especially those that are close to forms of research that pair research and activism (Cole, 1991; Nissen, 1998). Cogenerative dialogue is a reflective conversation among selected participants (Tobin, 2014). This reflection does not offer a quick quality improvement to educators and students but provides social space for educators and students. Both of them provide perspective on how they feel during the class process. The parties participating in the dialogue have the opportunity to improve each other (Martin, 2006).

Participants

In this study, participants consisted of two junior lecturers (JL-H & JL-I) who taught in the teacher training program, two senior teachers (ST-P & ST-R), four pre-service chemistry teachers (PCT), and school students. One of the main goals of cogenerative dialogue is to identify contradictions that might be changed to improve the quality of teaching and learning chemistry. Cogenerative dialogue is part of the critical pedagogical process (Tobin, 2014). Therefore, all participants are encouraged to express their opinions, identify specific examples related to chemical content that are difficult to learn and teach, as well as the characteristics of students during chemistry learning, all of which describe what parts need improvement. Besides, it also identifies examples of exemplary practices or disagreements on their examples that exemplify the need to change.

Data Collection and Analysis

To build meaning in a cogenerative dialogue session, we make a dialectical process consisting of two movements: understanding and explanation. Understanding is obtained directly about the condition of the practical situation that occurs and is a necessary prerequisite of all other forms of understanding (Ricoeur & Kearney, 2007), then continued on hermeneutic analysis to look for explanations on the direct understanding obtained so that the related theories can be obtained. The move from first understanding to this theory begins during cogenerative dialogue

sessions and often continues during face-to-face meetings or e-mail exchanges (Roth & Tobin, 2001) and chat through WhatsApp applications related to information regarding the chemistry learning process among participants. Dialogue about Technological Pedagogical Content Knowledge (TPACK) lead to questions (Harris et al., 2012) that are structured as TPACK-specific questions namely:
(1) How and why certain technologies used in chemistry learning "fit" the purpose of the content/process?;
(2) How and why do certain technologies used in chemistry learning "fit" the teaching strategies we used?;
(3) How and why are the learning objectives, teaching strategies, and technology used all "fit" together in chemistry learning?.

This discussion featured an ethnographic case study from the co-teaching and cogenerative dialogue on the chemistry learning about chemical bonding, elements, and laboratory introduction. The results of the dialogue provide a direction on how at the end efforts to make "Fit" on the criteria consisting of "Content" (Curriculum-based technology), "Pedagogy" (Using technology in teaching/learning), "Technology" (Compatibility of technology with curriculum goals & instructional strategies). In addition to interpreting the story of teaching experience, information is also obtained from the reflection of the learning outcomes provided by students of senior teachers, as well as videos of learning activities that they find interesting. The acquisition of reflection results was also obtained from the reports of pre-service teachers who carried out internships in the third and fourth years of their Bachelor of Education program. The SWOT analysis was used to provide an overview experienced by educators, as well as strategies planned.

Findings

The complexity of chemistry classrooms has required stakeholders to question, reflect, and take action to understand and correct problems related to the dynamics of students, educators, and curriculum. Critical pedagogy shows that changes in contemporary science classes (including chemistry classes) must involve educators who take an active role in creating critical awareness and utilize critical pedagogy, to produce meaningful learning outcomes (Kincheloe, 1998). Cogenerative dialogue research has provided a strong understanding of, and insight into, the complex forces that shape the teaching and learning of science and science education (Bayne & Scantlebury, 2012). The cogenerative dialogue begins with a huddle (Aubusson et al., 2006a) and discussions between senior teachers (ST) and junior lectures (JL) relating to their findings and experiences in teaching chemistry, including the internship experience provided by pre-service chemistry teachers (PCT). Co-generative dialogues occur when co-teachers (ST, JL, PCT, and students) discuss the issues that impact teaching and learning and collectively generate solutions to any problems (Scantlebury et al., 2008). Cogenerative dialogue is an open discussion where all the opinions and voices of participants have the same outstanding value, and the participants together produce a product (e.g. solving a problem in chemistry teaching and learning) (Martin, 2006). The discussion in this study is not only limited to face-to-face meetings but also discussions through long conversations via email, written reports, and chat via WhatsApp. The results of the initial dialogue involving ST and JL, which are cross-generation educators, show diversities in the strategies used in chemistry learning. A comparison of commonly used strategies can be seen in Table 1. Based on the four cases that happened to each cross-generation educators, we will analyze the potential of each to develop TPACK through cogenerative dialogue that has been implemented.

Table 1.
Comparison of Instructional Strategies on Difficult Chemistry Learning Material

Chemistry learning material	Difficulties in learning and teaching	Instructional Strategies ST-P	ST-R	JL-H	JL-I
Chemical bonding	It is not understood that chemical bonds can be divided into intramolecular and intermolecular attractions.	Class activities are dominated by student presentation activities with PowerPoint media.	Teaching is carried out by lecture and discussion methods. Students are asked for presentations with PowerPoint media, or students are asked to make molecular shapes with balloons, plasticine, wire, or plastic straws	Teaching chemistry uses analogies about chemical bonds with pair bonds that occur in the real world.	Teaching chemistry uses animated video media on chemical bonds and intermolecular forces, as well as answer questions
Chemical element	This material is considered the dullest to be taught and learned because there are too much scope and memorization demands.	Learning material about the elements is divided into several parts to be presented in front of the class by groups of students.	The division of students into groups to carry out presentations in front of the class.	Educators classify students and provide case studies related to chemical elements, and ask prospective teachers to play roles related to the use of these elements in everyday life.	Pre-service teachers are asked for discussion presentations and strengthening lecturers using videos about the elements downloaded from Youtube.
Laboratory introduction	Simple laboratory types of equipment are not studied and understood by students' details and functions, even though they will often be used for chemical lab work.	Students are invited to a chemical laboratory; then children are asked to find information on the internet about how to use laboratory equipment	Students are asked to seek information in advance via the internet about chemical laboratory equipment, the functions of each equipment, laboratory work regulations. Students discuss results in groups.	Initially, students are asked to draw the tools they know, then their knowledge is explored about how the tool functions.	Teaching chemistry utilizes virtual laboratory software to introduce the use of lab equipment, laboratory videos, and showcase simple laboratory tools available.

Discussion

In this section, we provide descriptions of the interactions of the four cross-generation educators that we analyzed for the process of improving the quality of their chemistry teaching, as well as the use of technology that they have and might carry out. We explain the context of each educator to provide a background for teaching and using their technology. We then dismantle the nature and level of their interactions with various ideas and beliefs, other people, and the technological environment influencing their teaching process.

Case 1: When You Have to Describe Electrons in Your Mind

ST-R is a certified female chemistry teacher with 18 years of teaching experience in a public school located in Semarang. One of the chemical content that is difficult to teach is chemical bonds. This chapter is closely related to the meaning of the submicroscopic level to be symbolic in the form of images and forms. The submicroscopic level is an unobservable world and can only be accessed with imagination (Bucat & Mocerino, 2009; Imaduddin & Haryani, 2019). Visual representations have great importance in the learning and teaching of chemistry (Alkan & Koçak Altundağ, 2015). ST-R revealed her difficulty in explaining intermolecular forces. She stated that the explanation of the intermolecular force is often not emphasized by the teacher, in contrast to the explanation of intramolecular chemical bonds consisting of ionic and covalent bonds. A short time has been taken for an explanation of intramolecular bonds. Problems related to intermolecular forces are also not found in many national exam questions. Based on her explanation, she previously did not provide an explanation of the association or classification of bonds into intramolecular and intermolecular bonds, so students often considered different chapters not related to each other.

As a basic chemistry lecturer, JL-H and JL-I, having five years of teaching experience at the college level, feel the need for students to understand the linkages of concepts through the classification of chemical bonds into intramolecular and intermolecular. JL-H used the metaphor and analogy to give an initial impression of the chemical bond material, and then it was related to the type of material found in their daily lives. The philosophical origins and education of this metaphor and analogy have resulted in a variety of significant literature and cognitive theories. Metaphors and analogies have the potential to improve the quality of science teaching and learning; promote high-level thinking; and produce new tools for interpreting science education research (Aubusson et al., 2006b). JL-I stated the need for caution and anticipation on the use of analogies in teaching chemistry because it could lead to misconceptions. The analogy is called a "two-edged sword" because the use of analogies produces the right knowledge, which is often accompanied by alternative conceptions. Students use their past knowledge, experience, and preferences to interpret analogies when they 'accept' analogies so that the analogies are in harmony with their current personal and social environment. It is called the construction of personal meaning (Harrison & Treagust, 2006). The development of high-level thinking skills requires considerable effort on the part of the teacher. They need to use various learning approaches to develop students' ability to transfer their knowledge and skills, critical thinking and problem-solving skills (Hadzhikoleva et al., 2019). JL-I usually emphasizes the understanding of submicroscopic forms through animated videos downloaded through the Youtube page.

Based on the huddle among participants, the use of virtual reality/augmented reality (VR/AR) was worth trying to construct the understanding of prospective teachers related to chemical bonds. Augmented Reality (AR) is an extension of Virtual Reality (VR). Unlike traditional VR, AR combines the real world and virtual world so that users can interact with virtual objects that are inserted in real scenes around them and get the most natural and original human-computer interaction experience (Salve et al., 2017). An augmented reality (AR) of a mobile game improved pre-service teachers' self-efficacy and attitudes that lead to the integration of AR pedagogy in future STEM classes (Burton et al., 2011). In line with the participatory design approach, the GeoSciTeach smartphone application supported the awareness of pre-service science teachers about integrating geospatial ideas into science (Price et al., 2014). Mobility, combined with other features that appear in augmented reality, can help facilitate contextual learning experiences. University teachers find that implementing augmented reality in lectures significantly enhances student learning and their teaching processes in pedagogical and technical terms (Rizov & Rizova, 2015).

The initiation of the practice of utilizing this technology was carried out by JL-I using the RApp chemistry application, as seen in Figure 1. RApp Chemistry is a mobile application that works with augmented reality systems to describe the periodic table of chemical elements. The primary purpose of RApp Chemistry is for students to study the periodic table and all its characteristics (Plata & Muñoz, 2017). It is available and accessed through https://play.google.com/store/apps/details?id=com.CreatingWare.RApp&hl=en. The initial construction is carried out by understanding the electrons and their configuration in the arrangement of the periodic table of elements and continuing to discuss the characteristics of elements based on their arrangement in the periodic table.

Figure 1.
The Use of Augmented Reality (AR) Technology to Understand the Position of Electrons

PCT showed enthusiasm in the use of AR, and reached the understanding of elemental arrangement patterns in the periodic system, and how the location of electrons in the atomic structure of each element influences the type of bond formed, and the polarity of molecules. PCT explained that the weakness of using AR is that not all students have cellphones that support AR programs. Only Android smartphones with cameras are needed to build a local AR environment (Salve et al., 2017). The anticipation of these obstacles is dealt with by group activities to use the AR application on observing the position of electrons in the atomic structure.

Case 2: Teaching Chemical Elements to My Students is So Boring

ST-P is a certified female chemistry teacher who has started teaching 20 years ago and has a magister degree in chemistry education. She is also the chief of the Teacher Consultation Group of Chemistry Subject in Kudus Regency since three years ago. During the dialogue session, she gave a very positive response because it provided an opportunity to share her teaching experience freely. Cogenerative dialogue involving two or more people who come together to talk about events or shared experiences and not limited to face-to-face meetings is also extended through online conversation activities. She felt that she needed a story-sharing session with fellow educators to improve the quality of herself as a professional teacher and improve the learning process she had carried out.

She began her story related to the difficulty in teaching material content of chemical elements that were felt so boring to be taught and learned by students. The following is a snippet of the dialogue that has been translated.

ST-P: *The boring learning material of chemistry subject to teach is chemical elements, isn't it?*

JL-I: *Yes, I agree. I also find it difficult to teach. The material was a challenge when I taught in tutoring first. It's full of memorization.*

ST-P: *I divide students into groups and ask them to present previously shared material. Even so, I feel that it is less effective and seems monotonous. What do you think?.*

JL-I: *When it comes to monotony, I have previously taught first-level students for presentations and allowed them to express themselves in their presentation techniques. Some of them* *have standard presentations using PowerPoint, some play drama stories related to chemistry, and some play diorama. The classroom atmosphere becomes more alive.*

ST-P: *Can they still master the material content?*

JL-I: *I did not force them to memorize the whole material. Providing opportunities to develop creativity, in my opinion, is more memorable and meaningful.*

ST-P: *It means that I can modify such as by making songs, comics, and so on. Good idea.*

Based on the conversation in the cogenerative dialogue that ST-P and JL-I felt that choosing a method for learning elemental chemistry was not easy. This material tends to be taught with presentations in the form of a material presented by groups of students. JL-H provides contextual learning alternatives by providing cases related to chemical elements and followed by role-playing activities related to the material content. Nevertheless, JL-I provides advice on activities that make the class no longer monotonous and more alive through the exploration of student creativity.

The co-teaching practice is carried out in the ST-P class by allowing students to produce chemical learning products in the form of song compositions, video clips, rhymes, poems, pictures, posters, comic strips, and their creative products. They are not limited to product types but are asked to show the relevance of what students make with elemental chemicals. When students are involved and motivated and feel minimal stress, information flows freely, and they reach a higher level of awareness. Such learning does not come from quiet classrooms or directed lectures, but from classrooms with an atmosphere of passionate discovery (Kohn, 2004). The learning approach applied to co-teaching was a joyful learning approach. A joyful learning approach is a learning approach that can create a pleasant learning atmosphere (Pangestika et al., 2017). This approach is applied through learning models that are designed to make students active, creative, innovative, and feel happy during the learning process so that students with their awareness want and love learning chemistry (Astriani et al., 2013). ST-P tried to make simple use of smartphone technology, which was for singing and playing music in chemistry learning activities as shown in Figure 2.

Figure 2.
ST-P's Students Used their Smartphone at a Chemistry Classroom Session to Sing Songs Related to Material

Students maintain what they learn when learning is associated with strong positive emotions (Dulay & Burt, 1977; Krashen, 1982). Cognitive psychology studies provide clinical evidence that stress, boredom, confusion, low motivation, and anxiety can individually interfere with learning (Christianson, 1992). ST-P realized that students need motivation and pleasure in learning. Students enjoy a more comfortable classroom atmosphere with song rhythms, funny videos, and selfie activities. The teacher is the instigator of the fundamental interactions with his/her students, and he/she can become an instigator like that only with well-organized teaching (Xhemajli, 2016). ST-P also recounted the learning strategies that had been carried out previously on other chemical subject matter, namely the rate of reaction, by making learning outside the classroom through the activity of burning skewers (Bahasa: sate).

ST-P was aware of the limitations of her ability to present technology-integrated learning. Even so, she felt technological developments were helpful. She gave an example of the use of e-mail and WhatsApp in providing information to classes and gathering assignments. ST-R stated that when watching chemistry learning integrated with technology, such as using virtual laboratory applications, the presentation looked so easy, but if she tried it by herself, it turned out that she was still struggling. Both believe that the generation of JL-H, JL-I, PCT, and their students are very adept at utilizing technology. ST-P directed the assignment integrating technology, although, in skill, she still felt left behind. The product created in the ST-P class can be seen in Figure 3.

Figure 3.
Students' Creations in the Form of a Comic Strip and Video Clip about the Material of Chemical Elements

An important note from the results of student reflections on learning about chemical elements is that some students feel that they did not understand the learning materials because students only master the material for their groups. Even so, students stated that they could develop their creativity, used technology to study chemistry, and enjoyed chemical learning organized by ST-P. JL-I provided advice on the use of periodic table applications that can be accessed through http://periodictableexplorer.com/pc.htm as shown in Figure 4. This application contains all elements of the Periodic Table, which are accompanied by images of elements in their natural state, as well as much other information and interactive displays (Freshney, 2016). Nevertheless, the constraints on using this application are that the language used is still in English so for ST, JL, PCT, and students must translate into Indonesian if needed.

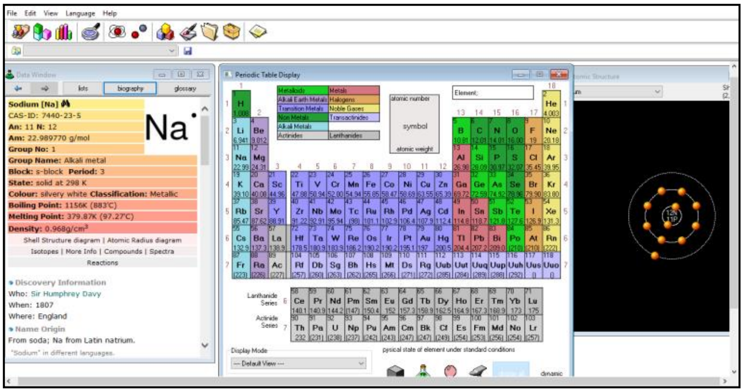

Figure 4.

One of the Computer and Smartphone Applications that can be Applied to Learning Chemistry about Elements (Periodic Table Explorer 1.9 Beta).

Case 3: What They See is not Necessarily What They Can Use

The introduction of chemical laboratories is needed by students, mainly the functions, specifications, and use of laboratory equipment that they will use in practical activities. Learning material about the introduction of chemical laboratories were included in the national high school curriculum for the first year. The laboratory has been identified as the heart of an excellent scientific program allowing students in schools to have experiences that are consistent with the objectives of scientific literacy (Akani, 2015). Based on the experience of ST-R & JL-H, high school students and even first-year teacher candidates do not understand the functions of laboratory equipment, even the names of simple laboratory equipment such as beakers, measuring cylinders, volumetric flasks, Erlenmeyer flasks, volumetric pipettes, burettes, and test tubes. JL-I also found that first-year students showed improper laboratory work in choosing tools for reacting materials. ST-P experienced a similar thing. Learning material about the introduction of chemical laboratories are taught in almost the same way by cross-generation educators.

Based on the results of the experiences obtained by participants, JL-I designed laboratory learning that not only utilized the laboratory directly but also by using a virtual laboratory. JL-I implemented the Crocodile Chemistry application to introduce laboratory equipment, chemical characteristics, and chemical reactions in virtual experiments. Crocodile Chemistry is a new simulation program presented by Crocodile Clips as shown in Figure 5. This simulation allows users to combine various reagents in exact quantities, using a variety of glass equipment options in the laboratory and materials including various kinds of acids, bases, metals, inorganic salts, gases, and indicators (Keith-Lucas, 2000).

Cogenerative dialogue can focus on implementing an activity, lesson, or assessment and provide opportunities for teachers to reflect on their teaching practices. Through collective teaching discussion, the teacher can become aware of the explicit and tacit aspects of teaching (Tobin et al., 2003). ST-R stated that she had been discussing with PCT regarding how to assess students' skills in carrying out practical work effectively. Observing and assessing students in detail when they carry out practical activities is not easy. Based on the dialogue of ST-R and PCT, ST-R provided flexibility for students to use smartphones as a medium for documenting their laboratory work, for example, documenting changes in the color of chemical reactions. This showed that the ST-R's learning strategy has seen opportunities for the use of technology to improve the quality of teaching chemistry. Digital technology is a handy academic tool in the realization of educational activities (Arsic & Milovanovic, 2016).

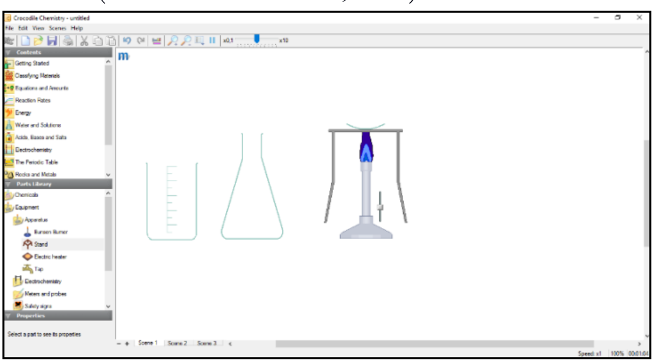

Figure 5.

Crocodile Chemistry Application View for Learning about the Introduction of Chemical Laboratories

ST-R considered students in the current era to be high-speed learning and utilizing technology. ST-R felt that her skill is lagging in utilizing technology for learning. Findings that represent lower ICT literacy for teachers compared to other civil servants reveal a problematic situation for the education community because it is usually expected that teachers have a higher level of ICT literacy than those from other workgroups to provide appropriate guidance for students (Soysal et al., 2019). Educators need to position appropriately for students in the implementation of learning activities and provide psychological assistance to utilize existing technology for learning resources (Putranta & Jumadi, 2019).

Nevertheless, ST-R realized that learning technology is essential for enhancing professionalism as an educator. When discussing the delivery of new technology to the classroom, educators address the problem known as the "double innovation" problem (Education.com, 2014). Double innovation shows additional work that must be done by the teacher. The teacher must first study technology well enough for the needs in the classroom before deciding how to integrate technology with the objectives and class curriculum. While educational technology has become easier to learn, the problem of dual innovation still shows the need for additional preparation. Ertmer (1999) showed that time is one of the most influential barriers to integrating new class technology. The time of a teacher is precious, and it is undeniable that one of the most frequently accepted challenges today is to integrate new technology into the classroom.

Strength, Weakness, Opportunity, and Threat (SWOT) Analysis for TPACKing Process

We reinterpret TPACK as TPACKing, which leads to an active process carried out by the teacher where he builds knowledge to teach in a technology-rich environment. TPACKing is the process of constructing knowledge and balance through which TPACK is unique for each educator (Olofson et al., 2016). When involved in the TPACKing process, educators strive to unite technological, pedagogical, and content knowledge and facilitate each other. We are interested in our experiences, past experiences, and knowledge of students in the process of building our TPACK. The educators then apply this TPACK to students and the environment, and this interaction mediates the next TPACK construction. When TPACKing, knowledge of cross-generation educators continues to be built and is assisted by experiential experiences so that the content of an educator's TPACK changes. Changes are generated in the innovations achieved and their beliefs about technology, pedagogy, and their content area. The following is presented in the SWOT analysis on the TPACKing process obtained from the summary of cogenerative dialogue that has been carried out as shown in Table 2.

Table 2.

SWOT Analysis of the Educators' TPACKing Process

P / F	**Enhancers**	**Inhibitors**
Internal	Strengths 1. Beliefs and attitudes of educators who always want to learn new things including the implementation of technology in classrooms 2. A willingness to collaborate and be open with changes and technological developments 3. The attitude of educators that provides opportunities for students to develop their technological skills	Weakness 1. Educators' attitudes and beliefs about the negative impact of technology integration into the classroom. 2. Low confidence in skills and knowledge given. The "digital natives" can intimidate educators, especially educators, with little technological experience. 3. Educator resistance to technology in the classroom
External	Opportunities 1. **Access**: Institutional policies that allow students to use smartphones during school hours have provided opportunities to develop mobile learning. The concept of Bring Your Own Device (BYOD) as proposed by Afreen (2014) can be implemented in institutions. Also, there are currently many PC or smartphone applications available to support the improvement of the quality of chemical learning. 2. **Training**: There has been much training on the development of TPACK provided free of charge (e.g.: http://etraining.seamolec.org/) which can be followed by educators of various levels of education. 3. **Support**: As Ertmer (1999) pointed out, the form of support during the initial phase of TPACKing is that educators need **more technical support** to use new technology. When	Threats 1. **Access**: insufficient equipment or connectivity 2. **Training:** inadequate training related to technology 3. **Support:** inadequate technical support and administrative/peer support.

P / F	Enhancers	Inhibitors
	educators become more proficient in technical skills, needs can shift to **administration and peer support** to help develop and implement technology in their classrooms. This type of support can be provided in **the professional learning community** (e.g. Microsoft Educator Community, which can be accessed via https://education.microsoft.com/) through regular discussions.	

P = Performances; **F**= Factors

With the development of new technologies for education, educators must continue to challenge themselves and explore whether these technologies support learning their content (Niess et al., 2009). Exploration must be part of a larger balance process that includes the influence of students and philosophical points of view. The involvement of internal factors in professional educators, as well as factors outside themselves concerning their interaction patterns with the community and technology, provides an overview of the process of developing educators' TPACK. The SWOT analysis showed internal and external factors that are the triggers and inhibitors of the educators' TPACKing process. The internal factors include the attitudes and beliefs of educators in trying new technologies for their classes, confidence in skills and knowledge, and the level of resistance to technology implementation. The external factors that play a role in TPACKing educators include access related to technological facilities and infrastructure, training provided for the development of educator technology skills, and support for the development of educators' TPACK. TPACKing is a process of equilibrating intrapersonal, technological, and interpersonal influences (Olofson et al., 2016). Advanced technology builds connections between users and their lives (Betoncu & Ozdamli, 2019).

Conclusion

The cogenerative dialogue was fruitful in catalyzing improvements in the chemistry teaching and learning quality. All participants participated in each method to provide an overview and improvement of a problem found in teaching and learning. Not only educators, both teachers and lecturers, students and pre-service teachers also provide advice and improvements to the quality of teaching.

The integration of teaching with technology has an impact both for internal educators and for the environment. Students are given an alternative to unconventional learning through optimizing the use of technology that may be mastered by educators. Educators have sought to integrate technology into content and pedagogical knowledge. In their efforts, educators provide space for themselves to learn technology and provide space for students to use technology and even teach it to educators. Positive interaction is felt when using technology as an essential tool for creating active chemical learning both in terms of providing comfortable nuances in the learning process and concretizing and jumping out understanding of chemical concepts. Through cogenerative dialogue, each educator inspires and is inspired, as well as students and pre-service chemistry teachers also provide direction of improvement, which is also a source of inspiration for educators to improve their pedagogical quality.

The next challenge is how to provide a more detailed picture of the TPACKing process that occurs in the personal educator, and how to grow TPACK by looking at the personal characteristics of the educator and the educator's environment. Thus, senior educators, junior lecturers, pre-service chemistry teachers, and students can enjoy current technology to accelerate the process of learning chemistry.

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References

Afreen, R. (2014). Bring Your Own Device (BYOD) in higher education: Opportunities and challenges. *International Journal of Emerging Trends & Technology in Computer Science*, *3*(1), 233–236.

Akani, O. (2015). Laboratory Teaching: Implication On Students' Achievement In Chemistry In Secondary Schools In Ebonyi State Of Nigeria. *Journal of Education and Practice*, *6*(4), 2016–2013.

Alkan, F., & Koçak Altundağ, C. (2015). The Role of Technology in Science Teaching Activities: Web Based Teaching Applications. *Journal for the Education of Gifted Young Scientists*, *3*(2), 1–7. https://doi.org/http://dx.doi.org/10.17478/JEGYS.2015213531

Arsic, Z., & Milovanovic, B. (2016). Importance of computer technology in realization of cultural and educational tasks of preschool institutions. *(IJCRSEE) International Journal of Cognitive Research in Science, Engineering and Education*, *4*(1), 9–15. https://doi.org/10.5937/ijcrsee1601009a

Astriani, D., Hadisaputro, S., & Nurhayati, S. (2013). Pengaruh Model Pembelajaran Joyfull Learning Berbantuan Media Dox-card pada Materi Pokok Redoks. *Chemistry in Education*, *2*(2252), 1–7.

Aubusson, P. J., Harrison, A. G., & Ritchie, S. M. (2006a). Metaphor and Analogy: Serious thought in science education. In *Metaphor and Analogy in Science Education* (Issue June). Springer. https://doi.org/10.1007/1-4020-3830-5

Aubusson, P. J., Harrison, A. G., & Ritchie, S. M. (2006b). Metaphor and Analogy: Serious thought in science education. In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), *Metaphore and Analogy in Science Education* (pp. 1–10). Springer.

Bayne, G. U., & Scantlebury, K. (2012). Using Cogenerative Dialogues to Expand and Extend Students' Learning. In *The Handbook of Educational Theories* (pp. 237–247). Information Age Publishing.

Betoncu, O., & Ozdamli, F. (2019). The Disease of 21 st Century : Digital Disease. *TEM Journal*, *8*(2), 598–603. https://doi.org/10.18421/TEM82-

Brown, K. K., Gilmore, M. W., Dillihunt, M., & Minor, K. (2018). Utilizing Online Technology to Effectively Teach Chemistry in Secondary Education. *Modern Chemistry & Applications*, *06*(01), 244. https://doi.org/10.4172/2329-6798.1000244

Bucat, B., & Mocerino, M. (2009). Learning at the Sub-micro Level: Structural Representations. In J. K. Gilbert & D. F. Treagust (Eds.), *Multiple Representation in Chemical Education: Models & Modelling in Science Education* (pp. 11–29). Springer.

Burton, E. P., Frazier, W., Annetta, L., Lamb, R., Cheng, R., & Chmiel, M. (2011). Modeling augmented reality games with preservice preservice elementary and secondary science teachers. *Journal of Technology and Teacher Education*, *19*(3), 303–329.

Chen, C. H., Liao, C. H., Chen, Y. C., & Lee, C. F. (2011). The integration of synchronous communication technology into service learning for pre-service teachers' online tutoring of middle school students. *Internet and Higher Education*, *14*(1), 27–33. https://doi.org/10.1016/j.iheduc.2010.02.003

Christianson, S. A. (1992). Emotional stress and eyewitness memory: A critical review. *Psychological Bulletin*, *112*(2), 284–309.

Cole, R. E. (1991). Participant Observer Research: An Activist Role. In W. F. Whyte (Ed.), *Participatory Action Research* (pp. 159–166). Sage Publications.

Dulay, H., & Burt, M. (1977). Remarks on creativity in language acquisition. In M. Burt, H. Dulay, & M. Finocchiaro (Eds.), *Viewpoints on English as a second language*. Regents.

Education.com. (2014). *Technology in the Classroom : Helpful or Harmful ?* https://www.education.com/magazine/article/effective-technology-teaching-child/

Eldon, M., & Levin, M. (1991). Cogenerative Learning: Bringing Participation into Action Research. In W. F. Whyte (Ed.), *Participatory Action Research* (pp. 127–142). Newbury Park.

Ertmer, P. A. (1999). Addressing First- and Second-Order Barriers to Change : Strategies for Technology Integration. *Educational Technology Research and Development*, *47*(4), 47–61. https://doi.org/10.1007/bf02299597

Freshney, P. A. (2016). *Periodic Table Explorer 1.9 beta*. Maximum Octopus. http://periodictableexplorer.com/pc_pte.htm

Hadzhikoleva, S., Hadzhikolev, E., & Kasakliev, N. (2019). Using peer assessment to enhance higher order thinking skills. *TEM Journal*, *8*(1), 242–247. https://doi.org/10.18421/TEM81-34

Harris, J., Grandgenett, N., & Hofer, M. (2012). Testing an instrument using structured interviews to assess experienced teachers' TPACK. In *Book Chapters* (Book 8, Issue Book 8). W&M Publish. http://publish.wm.edu/bookchapters/8

Harrison, A. G., & Treagust, D. F. (2006). Teaching and Learning with Analogies: Friend or Foe? In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), *Metaphore and Analogy in Science Education* (pp. 11–24). Springer.

Imaduddin, M. (2018). Analisis Miskonsepsi Submikroskopik Konsep Larutan pada Calon Guru Kimia. *Edu Sains: Jurnal Pendidikan Sains & Matematika*, *6*(2), 1. https://doi.org/10.23971/eds.v6i2.983

Imaduddin, M., & Haryani, S. (2019). Lembar Kerja Directed Activities Related to Texts (DARTs) Bermuatan Multipel Level Representasi untuk Meningkatkan Kemampuan Berpikir Kritis Calon Guru Kimia. *Jurnal Inovasi Pendidikan Kimia*, *13*(1), 2254–2267.

Jasmina Delceva. (2014). Classroom Management. *(IJCRSEE) International Journal of Cognitive Research in Science, Engineering and Education*, *2*(1), 51–56.

Johnson, A. M., Jacovina, M. E., Russell, D. G., & Soto, C. M. (2016). Challenges and solutions when using technologies in the classroom. In S. A. Crossley & D. S. McNamara (Eds.), *Adaptive Educational Technologies for Literacy Instruction* (pp. 13–29). Taylor & Francis. https://doi.org/10.4324/9781315647500

Keith-Lucas, L. (2000). Crocodile Chemistry (Crocodile Clips, Ltd.). *Journal of Chemical Education*, *77*(10), 1284. https://doi.org/10.1021/ed077p1284

Kincheloe, J. L. (1998). Critical research in science education. In B. J. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 1191–1205). Kluwer.

Kohn, A. (2004). Feel-bad education: The cult of rigor and the loss of joy. *Education Week*, *24*(3), 36–44.

Krashen, S. (1982). Theory versus practice in language training. In R. W. Blair (Ed.), *Innovative approaches to language teaching* (pp. 25–27). Newbury House.

Makovec, D. (2018). The teacher's role and professional development. *(IJCRSEE) International Journal of Cognitive Research in Science Engineering and Education*, *6*(2), 33–45. https://doi.org/10.5937/ijcrsee1802033m

Martin, S. (2006). Where practice and theory intersect in the chemistry classroom: Using cogenerative dialogue to identify the critical point in science education. *Cultural Studies of Science Education*, *1*(4), 693–720. https://doi.org/10.1007/s11422-006-9031-z

Mcglynn-stewart, M. (2015). From student to beginning teacher : Learning strengths and teaching challenges. *Cogent Education*, *2*(1), 1–18. https://doi.org/10.1080/2331186X.2015.1053182

Niess, M. L., Ronau, R. N., Shafer, K. G., Driskell, S. O., Harper, S. R., Johnston, C., Browning, C., Özgün-Koca, S. A., & Kersaint, G. (2009). Mathematics Teacher TPACK Standards and Development Model. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 4–24.

Nissen, M. (1998). Theory and practice: Happy marriage or passionate love affair? *Nordiske Udkast*, *26*(2), 79–84.

Obradović, B. P. (2013). Pedagogical practice way of connecting pedagogical theory and practice. *(IJCRSEE) International Journal of Cognitive Research in Science, Engineering and Education*, *1*(2), 152–163. http://dialnet.unirioja.es/servlet/articulo?codigo=4909354&info=resumen&idioma=ENG

Olofson, M. W., Swallow, M. J. C., & Neumann, M. D. (2016). TPACKing: A constructivist framing of TPACK to analyze teachers' construction of knowledge. In *Computers and Education* (Vol. 95). Elsevier Ltd. https://doi.org/10.1016/j.compedu.2015.12.010

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010).

Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers and Education*, *55*(3), 1321–1335. https://doi.org/10.1016/j.compedu.2010.06.002

Pangestika, R. R., Wijayati, N., & Widodo, A. T. (2017). Peningkatan Hasil Belajar Siswa melalui Pendekatan Joyfull Learning pada Pembelajaran Kimia. *Jurnal Inovasi Pendidikan Kimia*, *11*(1), 1849–1861.

Plata, D. H., & Muñoz, J. C. (2017). *RApp Chemistry*. https://abstracts.societyforscience.org/Home/PrintPdf/5093

Price, S., Davies, P., Farr, W., Jewitt, C., Roussos, G., & Sin, G. (2014). Fostering geospatial thinking in science education through a customisable smartphone application. *British Journal of Educational Technology*, *45*(1), 160–170.

Putranta, H., & Jumadi. (2019). Physics teacher efforts of Islamic high school in Yogyakarta to minimize students' anxiety when facing the assessment of physics learning outcomes. *Journal for the Education of Gifted Young Scientists*, *7*(2), 119–136. https://doi.org/10.17478/JEGYS.552091

Ricoeur, P., & Kearney, R. (2007). *From Text to Action: Essays in Hermeneutics, Ii*. Northwestern University Press.

Rizov, T., & Rizova, E. (2015). Augmented Reality As a Teaching Tool in Higher Education. *International Journal of Cognitive Research in Science, Engineering and Education*, *3*(1), 7–16.

Roth, W., & Tobin, K. (2001). The Implications of Coteaching/Cogenerative Dialogue for Teacher Evaluation : Learning from Multiple Perspectives of Everyday Practice. *Journal of Personnel Evaluation in Education*, *15*(1), 7–29.

Salve, S., Khapare, A., & Barve, R. (2017). Chemistry in Augmented Reality. *International Journal of Advanced Research in Computer and Communication Engineering*, *6*(3), 645–647. https://doi.org/10.17148/IJARCCE.2017.63151

Scantlebury, K., Gallo-Fox, J., & Wassell, B. (2008). Coteaching as a model for preservice secondary science teacher education. *Teaching and Teacher Education*, *24*(4), 967–981. https://doi.org/10.1016/j.tate.2007.10.008

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.1017/CBO9781107415324.004

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

Soysal, F., Çallı, B. A., & Coşkun, E. (2019). Intra and Intergenerational Digital Divide through ICT Literacy , Information Acquisition Skills , and Internet Utilization Purposes : An Analysis of Gen Z. *TEM Journal*, *8*(1), 264–274. https://doi.org/10.18421/TEM81-37

Stith, I., & Roth, W.-M. (2008). *Students in action: Cogenerative dialogue from secondary to elementary schools*. Sense Publisher.

Sung, B. (2007). Ways of Support for Beginning Teacher Induction in Elementary School. *Journal of Fisheries and Marine Sciences Education*, *19*(2), 310–322.

Szeto, E., & Cheng, A. Y. N. (2017). Pedagogies Across Subjects: What Are Preservice Teachers' TPACK Patterns of Integrating Technology in Practice? *Journal of Educational Computing Research*, *0*(0), 1–28. https://doi.org/10.1177/0735633116667370

Szeto, E., Cheng, A. Y. N., & Hong, J. C. (2015). Learning with Social Media: How do Preservice Teachers Integrate YouTube and Social Media in Teaching? *Asia-Pacific Education Researcher*, *25*(1), 35–44. https://doi.org/10.1007/s40299-015-0230-9

Tobin, Kenneth. (2006). Learning to teach through coteaching and cogenerative dialogue. *Teaching Education*, *17*(2), 133–142. https://doi.org/10.1080/10476210600680358

Tobin, Kenneth. (2007). The culture of science education. In K. Tobin & W.-M. Roth

(Eds.), *The changing faces of research in science education: A personal journey*. Sense Publisher.

Tobin, Kenneth. (2014). Twenty Questions about Cogenerative Dialogues. In Kenneth Tobin & A. Shady (Eds.), *Transforming Urban Education: Urban Teachers and Students Working Collaboratively* (pp. 181–190). Sense Publishers. https://doi.org/10.1007/978-94-6209-563-2

Tobin, Kenneth, Zurbano, R., Ford, A., & Carambo, C. (2003). Learning to teach through coteaching and cogenerative dialogue. *Cybernetics & Human Knowing*, *10*(2), 51–73.

Tømte, C., Enochsson, A. B., Buskqvist, U., & Kårstein, A. (2015). Educating online student teachers to master professional digital competence: The TPACK-framework goes online. *Computers & Education*, *84*, 26–35. https://doi.org/10.1016/j.compedu.2015.01.005

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2012). Technological pedagogical content knowledge: A review of the literature. *Journal of Computer Assisted Learning*, *29*(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Xhemajli, A. (2016). The Role of The Teacher in Interactive Teaching. *(IJCRSEE) International Journal of Cognitive Research in Science, Engineering and Education*, *4*(1), 31–38. https://doi.org/10.5937/IJCRSEE1601031X