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A Model of Online Teacher Professional Development in Chemical Subject of Middle School

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Abstract

With the continuous development of technology and people's dependence on the Internet, more and more teachers' professional development is carried out on the Internet. Since no one has studied the professional development of online middle school teachers, we did this study based on this research gap. This article is a research on the professional development of chemistry teachers based on the Internet. It uses content analysis methods to identify research questions and select keywords related to the topic, such as online teacher professional development, chemistry teacher professional development, secondary school teacher professional development and so on and codes the data. From this, we found that the strategies for the professional development of online teachers in middle school chemistry subjects includes chemical content, practice, guidance, exploratory experiment, online communication community, self-reflection, sustainability, continuity and action these eight parts. And online chemical TPD for student outcomes in middle school contains: gain knowledge, skills and confidence, determined their goals and plans, participate in scientific inquiry teaching and improve student performance, promote the transformation of students' scientific knowledge concepts, and have a positive influence on students' attitudes towards science.

Keywords: OTPD, teacher professional development, model, Chemical Subject, middle school

1. Introduction

Misra (2018) thought that teacher education and teacher professional development are essential to education improvement, which is conducive to improving teachers' skills, knowledge or beliefs so that they can better teach students and be teachers. However, it is not easy to promote teacher professional development. And it has many problems and challenges, such as not being tailor-made for teachers and being unable to adapt to the busy schedule of teachers (Trust & Pektas, 2018).

With the development of science and technology, people's reliance on the Internet has become a new way for teachers to obtain professional development. Ostashewski et al. (2011), which helps to teach teachers in accordance with their aptitude and is very convenient and carry out asynchronous discussions without time and space constraints (Parsons et al., 2019). Besides, Means et al. (2009) shows that teacher online learning is better than face-to-face learning: online professional development programs provided teachers online communities of practice which offered opportunities for reflection, a place to speak their thoughts and immersive virtual simulations. Online PD compared with the general professional development which relies on local resources, uses a wider range of resources (Wilson, 2013).

The quality of school teaching is related to the professional development of teachers in the field of subject knowledge and teaching methods, and there are few studies on the online professional development of middle school chemistry teachers. Mizzi (2020) provided that chemistry is one of the scientific disciplines and is also an experiment-based discipline. In the development of chemical science, regardless of the establishment of chemical theories, the determination of the composition and properties of substances must be based on experiments, while professional development is part of the exploitation and implementation of exploratory experiments. The chemical innovation brought by technology shocks us. For example, KryvyiRih State

Pedagogical University has created a database of chemical dishes and a virtual chemical laboratory, and the research had also shown that the application of AR technologies is potential in chemistry both in high school and secondary school.

Moreover, if science teachers lack proper professional development, they cannot teach in student-centered laboratories (Hofstein, Shore, & Kipnis, 2004). Science education is faced with overburdened courses and mostly traditional content. The abstraction of scientific concepts is not easy to understand. Science teaching is limited to the teaching of knowledge. Many countries are facing a series of problems such as a shortage of qualified science teachers (Van Driel et al., 2012). And for a long time, experimental activities are very important to the teaching work of chemistry teachers, so the teaching plan for chemistry teachers should be distinguished from other subjects, and the teaching should be carried out by exploratory experiments (O'Dwyer, 2018).

Due to the lack of online professional development for middle school chemistry teachers, our article will fill this gap. In this case, we start with the professional development of teachers, analyze its advantages and disadvantages, and then combine the current era background, the rapid development of network technology and online popularization of learning has made the professional development of online teachers inevitable (Lebec & Luft, 2007). In summary, this article is mainly to study some specific implementation content of the online professional development project for middle school chemistry teachers to improve students' outcomes. This article will create a model of online development for middle school chemistry teachers, provide professional development through social networks, and provide first-hand experience on online professional development for middle school chemistry teachers, and become a new way for middle school chemistry teachers to obtain professional development. Provide them with learning opportunities and platforms. One of the major innovations of our model is that it highlights the importance of experimentation in chemistry teaching (Taitelbaum et al., 2008). In online professional development, investigative teaching is integrated to allow them to reconstruct their chemical knowledge content (O'Dwyer, 2018).

In order to focus the review, two research questions were addressed, namely:

1) To explore online teacher professional development in Chemical subject

2) To build a model of online teacher professional development in Chemical subject of middle school

2. Literature Review

2.1 Teacher Professional Development

Major and Watson (2018) defined TPD as continuously formal professional learning. Teräs and Kartoğlu (2017) thought TPD is professionals who carry out new learning activities in their professional field. Additionally, Korthagen (2017) thinks PTD is a coordinated and unified activity towards self-core qualities, sense of identity, ideas, abilities, etc. TPD program Includes the following: 1) What the teacher teaches and how the students learn the contents. 2) Allow observing the students, which is conducive to the analysis of the students' work (Barab et al., 2003). 3) Provide sufficient and continuous time for educators to learn. 4) Attach importance to cooperation, build an interactive learning community, and allow teachers to participate collectively. 5) professional development is not enough to provide the required teaching needs, so it is important to provide teachers with opportunities to participate in the professional development of teachers' training on subject knowledge forwardly (Fishman et al., 2003; Guskey, 2000).

2.2 Online Teacher Professional Development

Curtis (2018) thought that online teacher professional development is built based on professional development which doesn't change its characteristics but extends it to new places, new ways and methods. OTPD is a project for teachers to participate in even and continuous TPD activity opportunities for educators through social networking sites (Ostashewski et al., 2011). Powell and Bodur (2019) found that online teacher professional development is through an online form, providing teachers with courses, seminars, etc. Fishman et al. (2013) defined online TPD as a teacher learning experience in whole or in part via the internet.

The online teacher professional development project includes the following: online professional development needs to have enough time to reflect and digest content. The literature on teacher learning and professional development requires long-term continuous professional development. The expected duration of professional development activities is important in two respects. First, longer events are more likely to provide an opportunity to discuss the content in depth. Second, activities that extend the time are more likely to allow teachers to try new practices in the classroom and obtain teaching feedback (King, 2002). In addition, providing teachers with training to support their teaching work can improve teachers' sense of self-efficacy, and it mainly includes two

parts; one is the training on theoretical knowledge and practical research, and the other is training on teaching strategies.

Qian et al. (2018) suggested online teacher professional development should provide content that focuses on the subject matter and how students learn it for teachers' professional development through teachers' needs for practice and related theories. Besides, according to teaching progress and teaching needs, provide teachers with guidance, such as teaching consultants to instruct teachers to learn professional knowledge and provide technical guidance (Bates & Morgan, 2018; Ma, Xin, & Du, 2018).

Furthermore, online teacher professional development needs to support teachers' reflective practice, which is conducive to improving student success. Use reflection as a tool to help teachers understand and improve the interaction with students, so that teachers can become professionals who can promote the development of students in the classroom. The learning of educators is not only focused on increasing the knowledge of teaching methods and content but also needs to Change the method of applying this knowledge in interpreting and responding to classroom situations. Continuously reflect and improve teaching practice (Rienties et al., 2013).

In addition, teachers should be provided with an online communication community, which is a lasting and sustainable personal social network. Educators use various forms of technology to communicate, share and develop an overlapping knowledge base. Its purpose is to provide continuous support for teachers' professional practice, break the national, ethnic, cultural, time and other restrictions, and it can be carried out at any time and place (Bustamante, 2020; Desimone, 2009; Liu, 2012).

Online TPD's advantages mainly include the following aspects: oTPD program (a) is convenient, timely and flexible, allowing teachers to adjust their progress and adapting to the teacher's schedule, who can also pursue learning that is more in line with their interests and needs and provided resources; (b) trains teachers to be exposed to new ideas, cultivates teachers' ability to reflect the former experience, think deeply, and work together; (c) is conducive to building up teachers' beliefs and confidence, and improving teachers' teaching practice ability (Bennison et al., 2020); (d) is synchronous where learning is done in real time, asynchronous where teachers learn in their own time, or synchronous and asynchronous at the same time (Terrazas-Arellanes et al., 2019).

A framework can be seen in Figure 1. It summarizes the online teacher professional development of paragraphs 2 to 5 in 2.2 and illustrates the advantages of online teacher professional development.

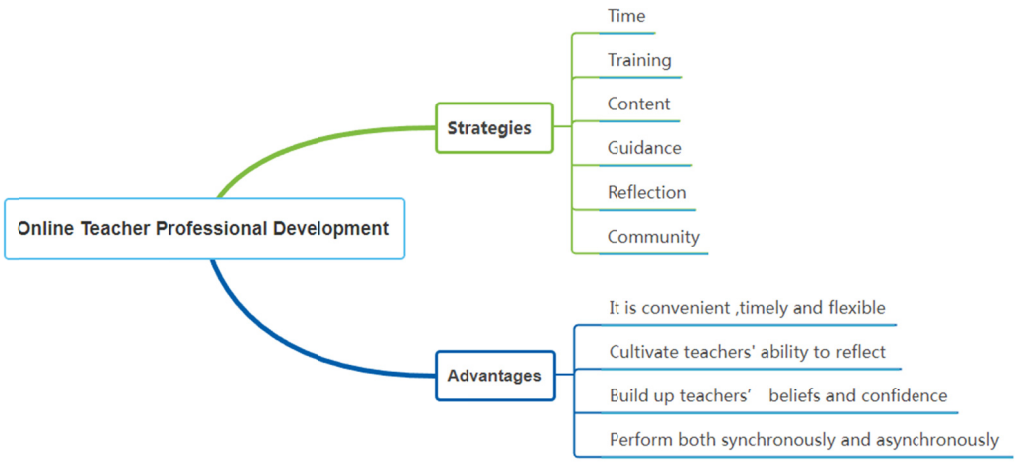

Figure 1. Strategies of online teacher professional development and its advantages

2.3 Teacher Professional Development in Science Subject

Science education faces many problems. For example, students' curriculum burden is heavy and traditional science content cannot reach modern students; students have difficulty in learning science because it touches abstract concepts and science teaching methods are also limited to the teaching of knowledge; many countries

face a shortage of qualified science teachers (Van Driel et al., 2012). In view of these problems, there are also certain enlightenments for teachers' teaching. Based on the findings of Van Driel et al. (2001), we sorted out its advantages in Figure 2.

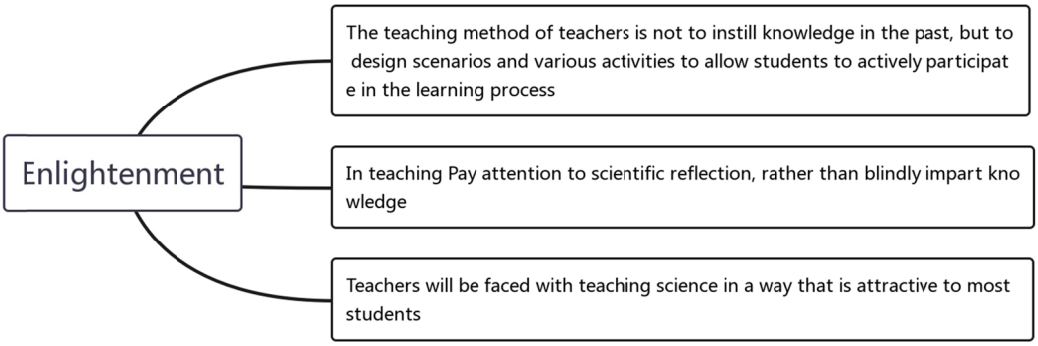

Figure 2. Enlightenment for teachers' teaching

In order to adapt to the new requirements of science teachers, the professional development of science teachers is essential and feasible. The professional development of high-quality science teachers includes:

- *Content*. Posnanski (2002) found out that the project must focus on the subject knowledge, deepen the teacher's content knowledge. A wealth of scientific content knowledge, coupled with the correct use of teaching methods that promote scientific learning, is the basis for effective science teaching.
- *Meeting*. Arrange regular project meetings to pay attention to problems in teaching, letting participants immerse themselves in inquiry, questioning, and experimentation to form an inquiry-based teaching model.
- *Duration and sustainability*. The time for professional development needs to be continuous and long-lasting (Rienties et al., 2013). Making professional development effective, takes a lot of time. One-time short-term intervention is not as effective as a long-term intervention. So, pay attention to the time for professional development not to be too short.
- *Common standards*. Based on common professional development standards and show teachers how to link their work with specific standards of student performance. The reforms of schools, regions, and states are consistent with policies and with the content of professional development.
- *Active learning*. In the whole project, teachers are voluntary and active participation. Active learning can be done by observing the teaching of expert teachers, being observed by other teachers, then feedback and discussion, to reviewing student work, all require teachers to actively participate.
- *Learning community*. Provide a learning community and establish meaningful connections with colleagues, To maintain the latest teaching research, cultivate cooperative relationships, and share effective teaching strategies (Clair et al., 2020).
- *Focus on practice*. There is a close relationship between high-quality professional development and teaching practice (Supovitz & Turner, 2000). Practical activities based on the principles of nature of science. Participants experience and analyze teaching methods through real experiences.

Among them, the professional development of science teachers focuses on the nature of the following scientific principles: a. empirical b. both reliable and triable c. based on observation and reasoning d. scientists use many methods to develop scientific knowledge. It is very important for teachers to have the opportunity to learn science so that they can deeply understand scientific thinking and participate in scientific practice. These opportunities provide teachers with a basis for thinking about subjects and their own teaching practices because science teachers need to provide students with complex scientific ideas, theories and explanations (Rosebery & Puttick, 1998).

2.4 Teacher Professional Development in Chemistry Subject

For chemistry teachers, TPD can deepen their understanding of science, inquiry and practice, improve teaching quality and transform inquiry skills into science teaching practice (Banilower et al., 2007). So, it mainly contains

these aspects:

1) *Content*. Set up seminars to provide pedagogical content knowledge training to chemistry teachers to improve their understanding of chemistry pedagogical content knowledge and deepen teachers' mastery of scientific knowledge (Jeanpierre, Oberhauser, & Freeman, 2005). And chemistry teachers need to know the importance of theories and concepts (Garnett et al., 1995). Because there are many abstract concepts in chemistry that cannot be directly perceived. So chemistry teachers should pay attention to the unity of content and process in teaching which helps to understand the process of inquiry methods (Loucks-Horsley et al., 2009).

2) *Practice*. Middle school chemistry teachers, as a participant, should carry out a professional practice which are experiments to be done by students before teaching to deepen their understanding of knowledge and content. The opportunity to participate in person can enhance the teacher's knowledge and skills, thus having a positive impact on practice. Although teachers are usually regarded as a unified collective, each teacher is also an independent individual. So chemistry teachers need to participate in the experience of simulation methods. This will help deepen the teacher's understanding of students' learning (Nechypurenko et al., 2020).

3) *Action*. Support teachers to implement organic chemistry in an action teaching plan. This teaching plan is designed and developed by practical chemistry teachers. The teaching plan focuses on inquiry, including practical work, molecular models and visual aids to promote conceptual understanding, and is designed for the high school chemistry syllabus.

4) *Continuity*. Participate continuously and provide teachers with continuous evaluation and improvement. However, all these studies show that in order for professional development to be effective, it takes a lot of time. One-off short-term intervention is not as effective as a long-term intervention

5) *Exploratory experiments*. Cultivate students' thinking, immerse them in experiments, understand and use problem-based teaching methods，which is used to train students with scientific literacy. Chemistry is an experiment-based subject, and science educators believe that participating in experiments is beneficial to students' learning.

6) *Self-reflection*. Chemistry teachers need to get feedback on their teaching from participants, which will help them to teach better. Instruct teachers to conduct meaningful self-reflection in practice. Pedagogical reflection is an important part of it, which is used to examine their teaching practice and improve their performance.

7) *Learning community*. Build a learning community promoting interactive learning between teachers and students and between students and students (Gröschner et al., 2018; Makovec, 2018).

3. Method

In order to get the research goals and the online professional development model for middle school chemistry teachers, this article uses content analysis. There are many different definitions of content analysis. For example, Stemler (2002) believed that content analysis is a method of analyzing various data. Neuendorf and Kumar (2015) defined content analysis as an objective and systematic analysis of system information. Cavanagh (1997) found that content analysis is a systematic, objective, and method of researching what you see, hear, and write data. Elo and Kyng (2008) stated the content analysis is a method for qualitatively or quantitatively analyzing data. And it can be used for induction and deduction. It contains the following aspects: 1) determine the research question, 2) choose the keywords of analysis, 3) code data, 4) summary of coding.

First of all, we must clarify the two issues which we want to study (Stemler, 2000). The first is to explore online teacher professional development in Chemical subjects. Since there is little content found by directly searching the literature on the professional development of middle school chemistry teachers, we will comprehensively study the online professional development of teachers and the professional development of middle school chemistry teachers. Among them, chemistry is one of the scientific disciplines, and we will also study Professional development extends to the professional development of science teachers. The previous part has studied the basic content of online teacher development, this part mainly looks for the content of chemistry teacher professional development. The second is to build a model of online teacher professional development in the Chemical subject of middle school. Second, choose the unit of analysis. Through the researcher's findings, it can be found that online teacher professional development can help improve teachers' practice and promote students' learning (Desimone, 2009).

Second, choose the keywords of analysis. The keywords of our article are online teacher professional development, teacher professional development in a science subject, chemical TPD in middle school and TPD in chemical major for student outcomes. All of the references in this article are included by Social Sciences Citation Index. For example, the first keyword we chose was online teacher professional development, and we

searched for relevant literature through the Scopus and Social Sciences Citation Index. Among them, we found the article teachers' perceptions of an online professional development experience: implications for a design and implementation framework, which contains the definition of online teacher professional development. Then we extracted and sorted out the concept of online teacher professional development. Write in our article.

Third and fourth, code data and summary of coding. When coding this article, we select the part of the literature we need to organize and summarize it into a word, sentence or paragraph. For example, in the development strategy of chemistry teachers, we read Loucks-Horsley's (2009) literature and found that practice is one of the strategies. We summarized the practice part in their literature into a paragraph to elaborate on the practice.

For example, in the first research question, when exploring the online professional development of chemistry teachers, we first studied the strategies of online teacher professional development. So the first keyword we chose was online teacher professional development, and we searched for relevant literature through the Social Sciences Citation Index. Among them, we found the article teachers' perceptions of an online professional development experience: implications for a design and implementation framework, which contains the definition of online teacher professional development. Then we extracted and sorted out the concept of online teacher professional development. Write in our article. Then we read Loucks-Horsley's (2009) literature and found that practice is one of the strategies. We summarized the practice part in their literature into a paragraph to elaborate on the practice.

4. Discussion and Analysis

The research results of content analysis are mainly the four circles in Figure 3, which are progressive. First, in the literature review part (that is, the first circle from the inside to the outside), we found five strategies for teacher professional development. The second circle from the inside to the outside includes three parts, namely, the strategy of chemistry teacher professional development, the strategy of middle school teacher professional development, and the strategy of online teacher professional development. The third circle from inside to outside includes two parts, namely, the online professional development strategy for chemistry teachers and the professional development strategy for middle school chemistry teachers.

Among them, the online professional development strategy of chemistry teachers is the integration of the chemistry teacher professional development strategy and the content of the online teacher professional development strategy. Similarly, the professional development strategy of middle school chemistry teachers is also the integration of the PD strategy of middle school teachers and chemistry teachers. The last circle is the model we finally built, the online professional development strategy for middle school chemistry teachers, which is the integration of the online professional development strategy for chemistry teachers and the professional development strategy for middle school chemistry teachers.

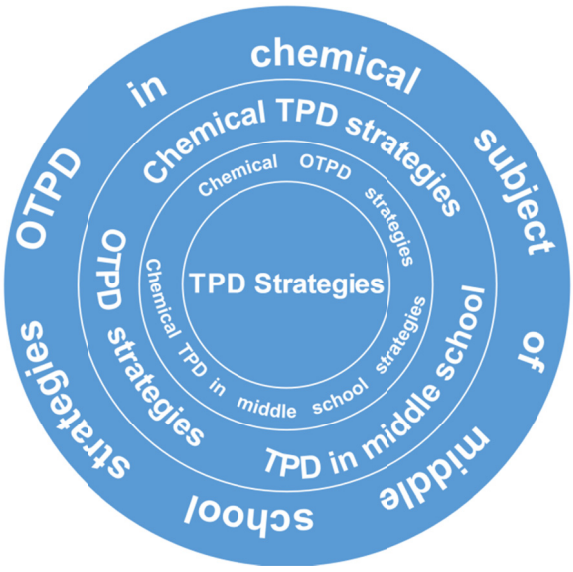

Figure 3. Network of TPD relationships

4.1 For Objective One Is to Explore Online Teacher Professional Development in Chemical Subjects

Online teacher professional development in chemical subjects should contains:

A. *Content*. Create content for chemistry teachers' professional development through teachers' practical needs and related scientific knowledge (Jeanpierre et al., 2005). The content includes chemistry subject knowledge, students learning, teaching and evaluation methods, environmental factors affecting teaching, and scientific teaching reforms, etc.

B. *Practice*. Improve practical skills and personally experience student experiments before class. Teachers need to transform from acquiring knowledge to classroom practice, applying what they have learned directly to teaching, and promoting the transformation of teaching practice.

C. *Exploratory experiments*. Chemistry teachers need to participate in an experience that simulates the methodologies. This will help deepen the teacher's understanding of students' learning.

D. *Online communication community*. Provide teachers with an online communication community, promote interaction and discussion among teachers. The online professional development community is an effective tool for training educators. The online communication community provides a way of information exchange through group collaboration.

E. *Self-reflection*. Chemical teachers need enough time to reflect, in order to get feedback on their teaching from participants and self-reflect, which will help them to teach better (Nechypurenko et al., 2020).

F. *Sustainability and continuity*. The minimum professional development activity time for teacher behavior changes ranges from 14 hours, 20 hours to 80 hours. But too much professional development time may be ineffective. It is difficult to determine an exact "critical point" because the optimal duration will depend on the professional development goals and the type of activity (Van Driel et al., 2012).

G. *Training*. Provide training to teachers to support their teaching work. Teachers need to transform from acquiring knowledge to classroom practice, applying their learning directly to teaching, and promoting the change of teaching practice. Teachers should also transform from traditional knowledge imparting to leading students to learn by doing through situational learning theory. Situational learning theory emphasizes that knowledge cannot be taught in an abstract way. To be useful, it must be located in a real environment and experienced through active learning (Rushton et al., 2011).

H. *Action*. Support teachers to implement organic chemistry action teaching plan. The content of organic chemistry in action teaching plan conforms to the key features that teachers consider important: it conforms to students' interests, allows students to work independently, and is connected with the teacher's knowledge and interests (O'Dwyer, 2018).

4.2 For Objective Two: Build a Model of Online Teacher Professional Development in Chemical Subject of Middle School

4.2.1 Chemical TPD in Middle School

TPD in middle school should pay attention to teamwork among interdisciplinary teachers helps to save time and solve problems together. Teachers need to pay more attention to technology-enhanced TPD (Thomas et al., 2012). Teachers apply theory to practice and reflect on students' learning, performance, application and motivation (Cooper & Stowe, 2018).

And research has found that the professional development of science teachers in middle school should follow closely scientific content, process skills and teaching methods need to be closely integrated; build a learning community where learners and participants cooperate with each other; participants learn cooperatively through group learning; the impact of a professional development model on middle school science teachers' efficacy and implementation of inquiry (Radford, 1998). Providing teachers with real experiences and enabling them to master skills and knowledge will have a positive impact on teachers' beliefs and practices, which improve the inquiry teaching efficiency and quality of science teachers in middle school (Capps, Crawford, & Constas, 2012; Lotter et al., 2016). According to Abell et al. (2013), Teachers' beliefs and attitudes towards science have an important influence on teachers' scientific practice.

In general, chemical TPD in middle school needs to conduct professional practice for teachers to deepen their understanding of the content being taught, understand and use methods to cultivate students' thinking to improve teachers' experimental skills. Moreover, form an interdisciplinary learning community to solve problems cooperatively to help teachers reflect on students' learning and performance (Ingvarson, Meiers, & Beavis, 2005).

4.3 Online Teacher Professional Development in Chemical Subject of Middle School

By reviewing the online professional development of chemistry teachers, the professional development of middle school chemistry teachers, etc., we concluded that the strategies of online professional development of middle school chemistry teachers should include the following content:

1) *Chemical content*. Pay attention to chemical content. Chemistry teachers need to know the importance of theories and concepts. Because many abstract concepts in chemistry cannot be directly perceived. The focus of teacher education and professional development projects has shifted from content knowledge to pedagogical knowledge related to specific content. Including teaching strategies and skills, the expression of scientific concepts, the expression of scientific concepts, the knowledge that makes these concepts difficult to learn, the knowledge that students misunderstand, the knowledge of students' previous knowledge or cognitive difficulties, and the understanding of students' local theories and epistemology (Jimoyiannis, 2010).

2) *Practice*. Focus on classroom practice. Practice before students practice and integrate practice into their classroom (Van Driel et al., 2012). If teachers also self-regulate their learning, especially if it is related to practical inquiry, there will be an additional value. By flexibly moving between self and coordinated learning and practice, teachers can repeatedly participate in acquiring resources to guide practice and generate knowledge through reflection on activities (Butler & Schnellert, 2012).

3) *Guidance*. Provide guidance according to the teacher's curriculum and teaching needs (Rienties et al., 2013). According to teaching progress and teaching needs, provide teachers with guidance. Which includes course organization, academic rigor, and tools used by teachers to promote learning (Van Driel et al., 2013).

4) *Exploratory experiments*. Chemistry is an experiment-based subject, and science educators believe that participating in experiments is beneficial to students' learning. Use exploratory experiments in the laboratory for chemistry teaching and integrate exploratory experiments into their chemistry classroom laboratory. Use exploratory experiments in the laboratory for chemistry teaching and integrate exploratory experiments into their chemistry classroom laboratory (Carmeli, & Hofstein, 2008).

5) *Online communication community*. Educators need to value cooperation, exchange ideas, and share strategies. Online communities are a source of professional learning for teachers. They are an active learning environment, where learners participate in conversations and inquiries through chat rooms, email lists, and posts to truly build relevance and meaning. The online community provides teachers with a wealth of professional learning resources. It is a valuable form of professional learning for teachers (Duncan-Howell, 2012).

6) *Self-reflection*. Provide teachers with enough time to reflect (Goldberg, 2019; Luvanga & Mkimbili, 2020; Neiles & Mertz, 2020). They need to get feedback on their teaching from participants, which will help them to teach better. Instructors to conduct meaningful self-reflection in practice. Pedagogical reflection is an important part, which is used to examine their teaching practice and improve their performance.

7) *Sustainability and continuity*. Project development requires a continuous and lasting long-term plan based on the experience and beliefs of teachers, based on the background of the times, and driven by student results (O'Dwyer, 2018). And it is difficult to determine an exact "critical point" because the optimal duration will depend on the professional development goals and the type of activity (Van Driel et al., 2012).

8) *Action*. Support teachers to implement organic chemistry in action plan. This teaching plan is designed and developed by practical chemistry teachers. The teaching plan focuses on inquiry, including practical work, molecular models and visual aids to promote conceptual understanding, and is designed for the high school chemistry syllabus.

4.4 TPD in the Chemical Major for Student Outcomes

Various studies have shown that professional development is conducive to improving student learning outcomes (Desimone & Pak, 2017), which among them, Ingvarson et al. (2005) showed that knowledge, practice and feedback are conducive to improving student learning outcomes which proves that if teachers deepen their understanding of what they teach, study students' learning styles, and strengthen cooperation with colleagues will help improve student learning outcomes.

Besides, Guskey and Yoon (2009) found that the reasonable arrangement of planning time and the teacher's firm grasp of the content taught are conducive to improving student learning outcomes. Lee, Longhurst, and Campbell (2017) thought that teachers' beliefs in scientific inquiry are related to students' achievement. Additionally, Gao (2019) agreed the teacher's pre-employment preparation is related to the student's performance, and professional development can provide teachers with sufficient pre-employment preparation.

Last, purposeful teacher cooperation helps improve student achievement (Davidovitch & Eckhaus, 2018).

4.5 Online Chemical TPD for Student Outcomes in Middle School

In summary, online chemical TPD in middle school contains the eight parts: create content for teachers' professional development through teachers' practical needs and related scientific knowledge; improve practical skills and personally experience student experiments before class; provide guidance to teachers according to teaching progress and teaching needs (Lawrie et al., 2019); cultivate students' thinking, immerse them in experiments, understand and use inquiry-based science teaching methods; provide teachers with an online communication community, promote interaction and discussion among teachers; provide teachers with enough time to reflect; build a learning community; understand and use methods to cultivate students' thinking (Luvanga & Mkimbili, 2020; Mixon et al., 2019).

According to research, the outcomes of professional development for students include the following aspect: first, students gain knowledge, skills and confidence. Secondly, students have determined their missions and plans. Third, students actively participate in scientific inquiry teaching and improve their performance. Fourth, it is beneficial to promote the transformation of students' scientific knowledge concepts. Fifth, have a positive influence on students' attitudes towards science.

As we mentioned earlier, the professional development of middle school chemistry teachers is conducive to the improvement of teachers' outcomes, which in turn will lead to the improvement of student outcomes. Their relationship is shown in Figure 4.

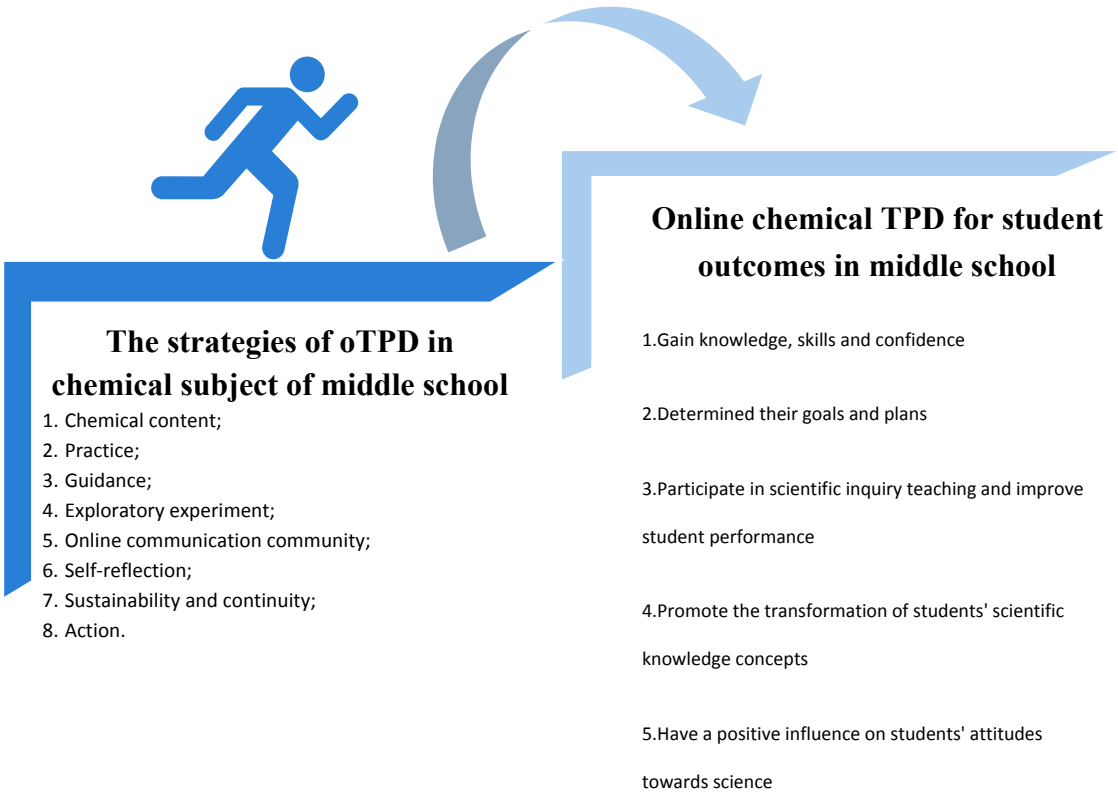

Figure 4. A model of online teacher professional development in Chemical Subject of middle school

5. Conclusion

In this article, we use content analysis methods, building a model of online teacher professional development in Chemical subject of middle school. It mainly includes two parts, one is the online professional development strategy for middle school chemistry teachers, and the other is the online chemical TPD for student outcomes in middle school. Online professional development strategy for middle school chemistry teachers mainly includes chemical content, practice, guidance, exploratory experiments, online communication community, self-reflection,

sustainability and continuity and action these are eight parts. And online chemical TPD for student outcomes in middle school contains: gain knowledge, skills and confidence, determined their goals and plans, participate in scientific inquiry teaching and improve student performance, promote the transformation of students' scientific knowledge concepts and have a positive influence on students' attitudes towards science. Develop an online professional development project for middle school chemistry teachers before entering the job. This model combines the teacher's subject and grade background, driven by student achievement, and provides teachers with flexible resources.

There are a lot of research on the professional development of online teachers. For example, Dede et al. (2009) have studied the key areas of professional development of online teachers and reviewed the current research on oTPD. Compared with previous research results, the innovation of this article is that we have studied the strategies of online teacher professional development in chemistry and middle school. For teachers, it trains teachers to be exposed to new ideas, cultivate teachers' ability to reflect on the former experience, think deeply, and work together. Additionally, conducive to building up teachers' beliefs and confidence, and improving teachers' teaching practice ability (Philipsen et al., 2019). For students, they developed self-efficacy and capacities. And the model determines their goals and plans, helps teachers participate in scientific inquiry teaching and improve student performance, which enhances the transformation of students' scientific knowledge concepts. Last it has a positive influence on students' attitudes towards science. The flaw of this article is that there is no quantitative data and it is not implemented in schools. Future research needs to apply this model to schools and create a questionnaire survey based on the professional development model of middle school chemistry teachers (Yurkofsky et al., 2019).

References

Abell, S. K., Appleton, K., & Hanuscin, D. L. (2013). *Handbook of research on science education*. Routledge.

Association For Learning Technology. (2009). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. Retrieved from http://repository.alt.ac.uk/id/eprint/629

Banilower, E. R., Heck, D. J., & Weiss, I. R. (2007). Can professional development make the vision of the standards a reality? The impact of the national science foundation's local systemic change through teacher enhancement initiative. *Journal of Research in Science Teaching*, *44*(3), 375–395. https://doi.org/10.1002/tea.20145

Barab, S. A., MaKinster, J. G., & Scheckler, R. (2003). Designing system dualities: Characterizing a web-supported professional development community. *Information Society*, *19*(3), 237–256. https://doi.org/10.1080/01972240309466

Bates, C. C., & Morgan, D. N. (2018). Seven elements of effective professional development. *Reading Teacher*, *71*(5), 623–626. https://doi.org/10.1002/trtr.1674

Bellibaş, M. Ş., & Gümüş, S. (2021). The effect of learning-centred leadership and teacher trust on teacher professional learning: Evidence from a centralised education system. *Professional Development in Education*, 1–13. https://doi.org/10.1080/19415257.2021.1879234

Bennison, A., Goos, M., & Geiger, V. (2020). Utilising a research-informed instructional design approach to develop an online resource to support teacher professional learning on embedding numeracy across the curriculum. *ZDM-Mathematics Education*, *52*, 1017–1031. https://doi.org/10.1007/s11858-020-01140-2

Bustamante, C. (2020). TPACK-based professional development on web 2.0 for Spanish teachers: A case study. *Computer Assisted Language Learning*, *33*(4), 327–352. https://doi.org/10.1080/09588221.2018.1564333

Butler, D. L., & Schnellert, L. (2012). Collaborative inquiry in teacher professional development. *Teaching and Teacher Education*, *28*(8), 1206–1220. https://doi.org/10.1016/j.tate.2012.07.009

Capps, D. K., Crawford, B. A., & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education*, *23*(3), 291–318. https://doi.org/10.1007/s10972-012-9275-2

Cavanagh, S. (1997). Content analysis: concepts, methods and applications. *Nurse Researcher*, *4*(3), 5–16. https://doi.org/10.7748/nr1997.04.4.3.5.c5869

Cooper, M. M., & Stowe, R. L. (2018). Chemistry education research-From personal empiricism to evidence, theory, and informed practice. *Chemical Reviews*, *118*(12), 6053–6087. https://doi.org/10.1021/acs.chemrev.8b00020

Curtis, A. (2018). Online Professional Development. *The TESOL Encyclopedia of English Language Teaching*, 1–7. https://doi.org/10.1002/9781118784235.eelt0135

Davidovitch, N., & Eckhaus, E. (2018). Effect of faculty on research cooperation and publication: Employing natural language processing. *Economics & Sociology*, *11*(4), 173. https://doi.org/10.14254/2071-789X.2018/11-4/11

Dede, C., Jass Ketelhut, D., Whitehouse, P., Breit, L., & McCloskey, E. M. (2009). A research agenda for online teacher professional development. *Journal of Teacher Education*, *60*(1), 8–19. https://doi.org/10.1177/0022487108327554

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181–199. https://doi.org/10.3102/0013189X08331140

Desimone, L. M., & Pak, K. (2017). Instructional coaching as high-quality professional development. *Theory into Practice*, *56*(1), 3–12. https://doi.org/10.1080/00405841.2016.1241947

Duncan-Howell, J. (2010). Teachers making connections: Online communities as a source of professional learning. *British Journal of Educational Technology*, *41*(2), 324–340. https://doi.org/10.1111/j.1467-8535.2009.00953.x

Edinger, M. J. (2020). What's in Your Gifted Education Online Teacher Professional Development? Incorporating Theory-and Practice-Based Elements of Instructional Learning Design. *Gifted Child Quarterly*, *64*(4), 304–318. https://doi.org/10.1177/0016986220938051

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Fishman, B., Konstantopoulos, S., Kubitskey, B. W., Vath, R., Park, G., Johnson, H., & Edelson, D. C. (2013). Comparing the impact of online and face-to-face professional development in the context of curriculum implementation. *Journal of Teacher Education*, *64*(5), 426–438. https://doi.org/10.1177/0022487113494413

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education*, *19*(6), 643–658. https://doi.org/10.1016/S0742-051X(03)00059-3

Gao, J. (2019). *Research on the Occupational Competence Promotion and Professional Development of Counselors in Private Colleges and Universities*. 2019 9th International Conference on Education, Management, and Computer.

Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education*, *25*(1), 69–96. https://doi.org/10.1080/03057269508560050

Goldberg, S. R. (2019). Dewey's Ideas in Action! Continuing Professional Development in an International Community of Practice. *Education and Culture*, *35*(1), 71–99. https://doi.org/10.5703/educationculture.35.1.0071

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today*, *24*(2), 105–112. https://doi.org/10.1016/j.nedt.2003.10.001

Gröschner, A., Schindler, A.-K., Holzberger, D., Alles, M., & Seidel, T. (2018). How systematic video reflection in teacher professional development regarding classroom discourse contributes to teacher and student self-efficacy. *International Journal of Educational Research*, *90*, 223–233. https://doi.org/10.1016/j.ijer.2018.02.003

Guskey, T. R. (2000). *Evaluating professional development*. Corwin press.

Guskey, T. R., & Yoon, K. S. (2009). What works in professional development? *Phi Delta Kappan*, *90*(7), 495–500. https://doi.org/10.1177/003172170909000709

Herrington, D. G., Yezierski, E. J., & Bancroft, S. F. (2016). Tool trouble: Challenges with using self‐report data to evaluate long‐term chemistry teacher professional development. *Journal of Research in Science Teaching*, *53*(7), 1055–1081. https://doi.org/10.1002/tea.21323

Hofstein, A., Shore, R., & Kipnis, M. (2004). Providing high school chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: A case study. *International Journal of Science Education*, *26*(1), 47–62. https://doi.org/10.1080/0950069032000070342

Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, student outcomes & efficacy. *Professional Development for Teachers and School Leaders*, *1*. https://doi.org/10.14507/epaa.v13n10.2005

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching*, *42*(6), 668–690. https://doi.org/10.1002/tea.20069

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education*, *55*(3), 1259–1269. https://doi.org/10.1016/j.compedu.2010.05.022

King, K. P. (2002). Identifying success in online teacher education and professional development. *Internet and Higher Education*, *5*(3), 231–246. https://doi.org/10.1016/S1096-7516(02)00104-5

Korthagen, F. (2017). Inconvenient truths about teacher learning: Towards professional development 3.0. *Teachers and Teaching*, *23*(4), 387–405. https://doi.org/10.1080/13540602.2016.1211523

Kunst, E. M., van Woerkom, M., & Poell, R. F. (2018). Teachers' goal orientation profiles and participation in professional development activities. *Vocations and Learning*, *11*(1), 91–111. https://doi.org/10.1007/s12186-017-9182-y

Lawrie, G. A., Schultz, M., Bailey, C. H., & Dargaville, B. L. (2019). Personal journeys of teachers: an investigation of the development of teacher professional knowledge and skill by expert tertiary chemistry teachers. *Chemistry Education Research and Practice*, *20*(1), 132–145. https://doi.org/10.1039/C8RP00187A

Lebec, M., & Luft, J. (2007). A mixed methods analysis of learning in online teacher professional development: A case report. *Contemporary Issues in Technology and Teacher Education*, *7*(1). 554–574. Retrieved from http://www.citejournal.org/vol7/iss1/general/article1.cfm.

Lee, H., Longhurst, M., & Campbell, T. (2017). Teacher learning in technology professional development and its impact on student achievement in science. *International Journal of Science Education*, *39*(10), 1282–1303. https://doi.org/10.1080/09500693.2017.1327733

Liu, K. Y. (2012). A design framework for online teacher professional development communities. *Asia Pacific Education Review*, *13*(4), 701–711. https://doi.org/10.1007/s12564-012-9230-0

Lotter, C., Smiley, W., Thompson, S., & Dickenson, T. (2016). The impact of a professional development model on middle school science teachers' efficacy and implementation of inquiry. *International Journal of Science Education*, *38*(18), 2712–2741. https://doi.org/10.1080/09500693.2016.1259535

Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2009). *Designing Professional Development for Teachers of Science and Mathematics*. Corwin press.

Luvanga, B. G., & Mkimbili, S. T. (2020). Views on Inquiry-based Chemistry Teaching Practice: Linking Contextual Challenges and Specific Professional Development Needs in Some Tanzanian Schools. *African Journal of Research in Mathematics Science and Technology Education*, *24*(3), 400–410. https://doi.org/10.1080/18117295.2020.1843259

Ma, N., Xin, S., & Du, J.-Y. (2018). A peer coaching-based professional development approach to improving the learning participation and learning design skills of in-service teachers. *Journal of Educational Technology & Society*, *21*(2), 291–304.

Makovec, D. (2018). The teacher's role and professional development. *International Journal of Cognitive Research in Science, Engineering and Education*, *6*(2), 33–46. https://doi.org/10.5937/ijcrsee1802033M

Mamlok-Naaman, R., Eilks, I., Bodner, G., & Hofstein, A. (2018). *Professional development of chemistry teachers: Theory and practice*. Royal Society of Chemistry.

McLeod, G. A., Vaughan, B., Carey, I., Shannon, T., & Winn, E. (2020). Pre-professional reflective practice: Strategies, perspectives and experiences. *International Journal of Osteopathic Medicine*, *35*, 50–56. https://doi.org/10.1016/j.ijosm.2019.11.005

Misra, P. (2018). MOOCs for teacher professional development: reflections and suggested actions. *Open Praxis*, *10*(1), 67–77. https://doi.org/10.5944/openpraxis.10.1.780

Mixon, C. S., Owens, J. S., Hustus, C., Serrano, V. J., & Holdaway, A. S. (2019). Evaluating the impact of online professional development on teachers' use of a targeted behavioral classroom intervention. *School Mental Health*, *11*(1), 115–128. https://doi.org/10.1007/s12310-018-9284-1

Mizzi, D. (2020). Supporting science teachers teaching outside specialism: Teachers' views of a professional development programme. *European Journal of Teacher Education*, 1–20. https://doi.org/10.1080/02619768.2020.1793951

Nechypurenko, P. P., Stoliarenko, V. G., Starova, T. V., Selivanova, T. V., Markova, O. M., Modlo, Y. O., & Shmeltser, E. O. (2020). *Development and implementation of educational resources in chemistry with elements of augmented reality*.

Neiles, K. Y., & Mertz, P. S. (2020). *Professional skills in chemistry and biochemistry curricula: A call to action*. In Integrating Professional Skills into Undergraduate Chemistry Curricula. American Chemical Society. https://doi.org/10.1021/bk-2020-1365.ch001

Neuendorf, K. A., & Kumar, A. (2015). Emerging trends in content analysis. *The International Encyclopedia of Political Communication*, *1*(May), 1–10. https://doi.org/10.1002/9781118541555.wbiepc065

O'Dwyer, A. (2018). An insight into how a constructivist professional development program can influence practice in six high school chemistry classrooms. *Journal of Science Teacher Education*, *29*(5), 353–377. https://doi.org/10.1080/1046560X.2018.1457348

Ostashewski, N. M., Reid, D., & Moisey, S. (2011). Applying constructionist principles to online teacher professional development. *International Review of Research in Open and Distributed Learning*, *12*(6), 143–156. https://doi.org/10.19173/irrodl.v12i6.976

Parsons, S. A., Hutchison, A. C., Hall, L. A., Parsons, A. W., Ives, S. T., & Leggett, A. B. (2019). US teachers' perceptions of online professional development. *Teaching and Teacher Education*, *82*(1), 33–42. https://doi.org/10.1016/j.tate.2019.03.006

Philipsen, B., Tondeur, J., McKenney, S., & Zhu, C. (2019). Supporting teacher reflection during online professional development: A logic modelling approach. *Technology Pedagogy and Education*, *28*(2), 237–253. https://doi.org/10.1080/1475939X.2019.1602077

Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education*, *13*(3), 189–220. https://doi.org/10.1023/A:1016517100186

Powell, C. G., & Bodur, Y. (2019). Teachers' perceptions of an online professional development experience: Implications for a design and implementation framework. *Teaching and Teacher Education*, *77*, 19–30. https://doi.org/10.1016/j.tate.2018.09.004

Prestridge, S. (2017). Conceptualising self-generating online teacher professional development. *Technology Pedagogy and Education*, *26*(1), 85–104. https://doi.org/10.1080/1475939X.2016.1167113

Qian, Y., Hambrusch, S., Yadav, A., & Gretter, S. (2018). Who needs what: Recommendations for designing effective online professional development for computer science teachers. *Journal of Research on Technology in Education*, *50*(2), 164–181. https://doi.org/10.1080/15391523.2018.1433565

Radford, D. L. (1998). Transferring theory into practice: A model for professional development for science education reform. *Journal of Research in Science Teaching*, *35*(1), 73–88. https://doi.org/10.1002/(SICI)1098-2736(199801)35:1<73::AID-TEA5>3.0.CO;2-K

Rienties, B., Brouwer, N., & Lygo-Baker, S. (2013). The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology. *Teaching and Teacher Education*, *29*, 122–131. https://doi.org/10.1016/j.tate.2012.09.002

Rosebery, A. S., & Puttick, G. M. (1998). Teacher professional development as situated sense‐making: A case study in science education. *Science Education*, *82*(6), 649–677. https://doi.org/10.1002/(SICI)1098-237X(199811)82:6<649::AID-SCE2>3.0.CO;2-H

Rushton, G. T., Lotter, C., & Singer, J. (2011). Chemistry teachers' emerging expertise in inquiry teaching: The effect of a professional development model on beliefs and practice. *Journal of Science Teacher Education*, *22*(1), 23–52. https://doi.org/10.1007/s10972-010-9224-x

St. Clair, T. L., Wheeler, L. B., Maeng, J. L., & Bell, R. L. (2020). Mixed-methods analysis of science teacher educator professional development: A five-year longitudinal study. *Professional Development in Education*, 1–24. https://doi.org/10.1080/19415257.2020.1787191

Stemler, S. (2000). An overview of content analysis. *Practical Assessment Research and Evaluation*, *7*(1), 17.

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching*, *37*(9), 963–980. https://doi.org/10.1002/1098-2736(200011)37:9<963::AID-TEA6>3.0.CO;2-0

Taitelbaum, D., Mamlok‐Naaman, R., Carmeli, M., & Hofstein, A. (2008). Evidence for teachers' change while participating in a continuous professional development programme and implementing the inquiry approach in the chemistry laboratory. *International Journal of Science Education*, *30*(5), 593–617. https://doi.org/10.1080/09500690701854840

Teräs, H., & Kartoğlu, Ü. (2017). A grounded theory of professional learning in an authentic online professional development program. *International Review of Research in Open and Distributed Learning*, *18*(7). https://doi.org/10.19173/irrodl.v18i7.2923

Terrazas-Arellanes, F. E., Strycker, L. A., & Walden, E. D. (2019). Web-based professional development model to enhance teaching of strategies for online academic research in middle school. *Journal of Research on Technology in Education*, *51*(2), 118–134. https://doi.org/10.1080/15391523.2018.1564637

Thomas, C. N., Hassaram, B., Rieth, H. J., Raghavan, N. S., Kinzer, C. K., & Mulloy, A. M. (2012). The integrated curriculum project: Teacher change and student outcomes within a university-school professional development collaboration. *Psychology in The Schools*, *49*(5), 444–464. https://doi.org/10.1002/pits.21612

Trust, T., & Pektas, E. (2018). Using the ADDIE model and universal design for learning principles to develop an open online course for teacher professional development. *Journal of Digital Learning in Teacher Education*, *34*(4), 219–233. https://doi.org/10.1080/21532974.2018.1494521

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, *38*(2), 137–158. https://doi.org/10.1002/1098-2736(200102)38:2<137::AID-TEA1001>3.0.CO;2-U

Van Driel, J. H., Meirink, J. A., van Veen, K., & Zwart, R. (2012). Current trends and missing links in studies on teacher professional development in science education: A review of design features and quality of research. *Studies in Science Education*, *48*(2), 129–160. https://doi.org/10.1080/03057267.2012.738020

Wilson, S. M. (2013). Professional development for science teachers. *Science*, *340*(6130), 310–313. https://doi.org/10.1126/science.1230725

Yurkofsky, M. M., Blum-Smith, S., & Brennan, K. (2019). Expanding outcomes: Exploring varied conceptions of teacher learning in an online professional development experience. *Teaching and Teacher Education*, *82*, 1–13. https://doi.org/10.1016/j.tate.2019.03.002