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A Study on Using Hands-on Science Inquiries to Promote the Geology Learning of Preservice Teachers

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Abstract

This study aims to investigate the geology learning performance of preservice teachers. A total of 31 sophomores (including 11 preservice teachers) from an educational university in Taiwan participated in this study. The course arrangements include class teaching and hands-on science inquiry activities. The study searches both quantitative and qualitative data as the sources for the analyses. The quantitative data are taken from the results of four specimen identification tests; the respondents are required to take a pre-test before teaching and then practice the explorative hands-on science activities. Afterwards, the scores of test results are used as the foundation of the analyses. The qualitative data are the feedback from the preservice teachers in the study. The research results show the results of the four post-tests are significantly better than those of the four pre-test scores, indicating the preservice teachers' concepts of minerals and rocks significantly improved. The analysis of the qualitative data also found the preservice teachers demonstrate a good understanding on geology content during geological inquiries. According to the research results, this study believes the cultivation of and training in hands-on geology inquiries can actually enhance preservice teachers' learning performances in geology.

Key words: Geology, Geoscience education, Hands-on science inquiry, Science learning, Science teacher education

Introduction

The 21st century is an age of knowledge. In such a knowledge-based economy, knowledge has evolved into a kind of productivity and competitiveness. More and more attention is now being given to how to enhance the advantages and competitiveness of a knowledge-based economy and how to strengthen the professional development of preservice teachers in colleges. With respect to the standards required for the professional development of science teachers, the National Research Council (1996) pointed out science teachers must meet the following requirements, including: (1) Teachers of science must learn essential science content through the perspectives and methods of inquiry. (2) Teachers of science must integrate knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching. (3) Teachers of science must build understanding and the ability for lifelong learning. To summarize, substantial scientific knowledge is the first step in the professional development of science teachers. It is also the basic task for teacher preparation of preservice teachers.

Second, with respect to hands-on science inquiries, the National Research Council (2000) also emphasized the use of inquiry as the main strategy when delivering science content. Li, Yang, and Chung (2009) pointed out during a scientific inquiry, scientists can continue to raise questions from curiosity, and then use scientific methods to solve these questions. When solving questions, they will develop many ingenious ways of thinking. A hands-on science inquiry usually contains four major steps: (1) Observation: observation is the process of using one or a variety of sensory organs and instruments to acquire information from the environment. All kinds of questions come from observations. Observational results can be qualitative or quantitative. A qualitative observation does not contain figures, while a quantitative observation contains both figures and units. (2) Hypotheses and deductions: hypotheses are explanations given by scientists to observational results. One observed phenomena may have different hypotheses. These can either be correct or false. Deductions refer to the conclusions reached by logical thinking and are based on existing information. They can either be correct or false. (3) Predictions: predictions mean scientists use their imagination to predict possible results based on hypotheses and deductions. Predictions can either be correct or false. And (4) Experiment and verification:[*]

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Scientists collect new information using observations or experiments to confirm whether hypotheses are proper or that their predictions are correct. In other words, scientists use the new information obtained from observations or experiments to confirm the correctness of their hypotheses and predictions. Therefore, when assisting science teachers to obtain substantial scientific knowledge, we must teach them to have good hands-on science inquiry skills.

The geology curriculum in college is an important professional curriculum for preservice science teachers, and the professional development of such teachers has a crucial influence on the science education in primary schools in the future. To promote the innovative effects of science and technology curriculums and the teaching in primary schools in Taiwan, and to foster qualified citizens in the 21st century, we need to continuously strengthen the efficiency of the training of science teachers, and enhance the career development of preservice teachers (in colleges) of primary schools. This will help to continue to enhance the learning outcomes of primary school students in the fields of science and technology.

Therefore, to enhance the efficiency of preservice teachers in science teaching, it is necessary to explore the professional abilities of preservice teachers in colleges with regards to science, and to establish a superior support system for their professional development. This will help guarantee the sufficient and necessary assistance and support for preservice teachers to acquire professional abilities in science, enable their professional development in science, and enhance the professional qualities of preservice primary school science teachers in Taiwan. They will then be able to thoroughly adapt to the new educational environment of the 21st century, which is a technological, informative, and knowledge-based economy, to achieve the goal of cultivating sound citizens for the new century.

Targeting the implementation of the geology curriculum in colleges, the study aims to investigate the learning performances of preservice teachers in colleges using hands-on science inquiry strategies and schemes. The research emphasis is to complete a hands-on science inquiry scheme by establishing the content and a model for the professional development of a geology curriculum in colleges, thus promoting the professional growth of preservice teachers' knowledge and skills in geology, and achieving the goal of enhancing the science teaching effects of primary schools.

Literature Review

Geoscience education

The curriculum and instruction of geology is generally called geoscience education at the stage of college education, and its main scope of exploration is the geosphere in the Earth system. King (2008) pointed out geoscience education focuses on cultivating learners' understanding of Earth materials, the effects of Earth activities, and Earth structure, etc.

Second, in elementary education in Taiwan, the curriculum and instruction of geology is generally included in the fields of science and technology, and the main content includes the educational connotations of the Earth system science. Dal (2009) further pointed out the core content of Earth system science education should contain discussions on the following four themes, including: (1) the structure of the Earth, (2) the dynamic evolutionary mechanism of every earth shell, (3) the role and the movement of the Earth in the planetary system, and (4) organisms on Earth.

With respect to the curriculum and content of geology, among the major items in the field of science and technology in the primary school Grade 1-9 curriculum in Taiwan, sub-themes on geology explore the substances that compose the Earth, and changes in the Earth's surface and crust, stratums and fossils, etc. (The Ministry of Education, 2008). After further examination of the learning content of geology in primary schools, it is discovered the main content includes the observation, inquiry, and appreciation of minerals, rocks, changes in the Earth's surface and crust, natural resources and energies, etc. This geological content is exactly the knowledge that primary school teachers should possess for the teaching of science and technology. Consequently, when this study discusses the professional development and knowledge ability of geology for preservice teachers in colleges, the discipline and concepts are mainly concerned with "minerals, rocks, and changes in the Earth's surface and crust".

Learning and teaching strategies of geology

According to the above, the learning content of the geology curriculum is mainly concerned with the observation, inquiry, and appreciation of minerals, rocks, and changes in the Earth's surface and crust. However, for students, the learning strategy for geology should not focus only on memorizing and reciting facts. They need to learn geology through scientific inquiry (Apedoe, 2008; National Research Council, 2000; The Ministry of Education, 2008). With respect to the cultivation of the ability for inquiry regarding geology, both Apedoe (2008) and the National Research Council (2000) emphasized strengthening learners' experiences and learning in the following five inquiry processes: (1) critical issues in applying science, (2) finding and proposing evidence, (3) using evidence to develop explanations that answer key scientific problems, (4) assessing explanations, and (5) communicating and debating the explanations.

However, many researchers have discovered students have several misconceptions about geology. These include: (1) the misconception of minerals, rocks, and fossils (Dal, 2009; Dove, 1997, 1998; Ford, 2005; Happs, 1982, 1985; Kusnick, 2002; Russell, Bell, Longden, & McGigan, 1993; Sharp, Mackintosh, & Seedhouse, 1995); (2) misconceptions of geological processes and time (Dal, 2005, 2007, 2009; Trend, 1998, 2000, 2001; Zen, 2001); (3) misconceptions of earthquakes, plate tectonics, and the structure of the Earth (Barrow & Haskins, 1996; Kali & Orion, 1996; Lillo, 1994; Marques & Thompson, 1997; Rutin & Sofer, 2007; Sneider & Ohadi, 1998); and (4) misconceptions of the water cycle (Asarraf & Orion, 2009; Bar, 1989; Kali, Orion, & Eylon, 2003). Consequently, an important topic for the geology curriculum and instruction is how to find ways to correct students' misconceptions, and establish the correct understanding of geological processes and phenomena.

To improve the students' learning regarding the concepts of different units of geology, and reduce their misconceptions of geology, many researchers have proposed different teaching methods and strategies, and such teaching has demonstrated good results (Allison, 2005; Bereki, 2000; Constantopoulos, 1994; Gibson, 2001; Kali, Orion, & Eylon, 2003; Veal & Chandler, 2008; Wellner, 1997).

With respect to mineral-themed study, Constantopoulos (1994) discovered using a jigsaw cooperative learning approach to guide students when learning about minerals could increase their mineralogy scores, class participation, learning motivation, and learning enthusiasm. Additionally, Gibson (2001) used models to create learning activities to guide students on how to conduct inquiry learning in respect to rocks and minerals. The study results show specific operations and the model inquiries for mineral crystals and rocks can increase students' recognition and understanding of rocks and minerals, and improve their ability to identify the different features of rocks and minerals. With respect to the recognition and identification of minerals, Allison (2005) pointed out adopting optimal and sub-optimal learning models of inquiry had better learning outcomes than that of mechanically memorizing the seven major features of minerals. The study results show both learning effects and the interest of students who adopt optimal and sub-optimal leaning models of inquiry are significantly improved.

With respect to the inquiry into rocks and stratums, Wellner (1997) used a spatial model of a topographic map to teach the formation of stratums. The study results show such a teaching activity contributes to students' understanding of the concepts and formation process of stratums. Second, Bereki (2000) used specimens of sedimentary rocks, metamorphic rocks, and igneous rocks to conduct a hands-on inquiry of the rock cycle. The study results show hands-on observation, inquiry, and experience can effectively promote students' understanding of the concept of the rock cycle. Additionally, the study by Kali, Orion, and Eylon (2003) discovered knowledge integration activities could effectively promote students' learning achievements in respect of the rock cycle.

Further, Veal & Chandler (2008) also pointed out the substation learning approach to science was beneficial to the understanding of the rock cycle, and training in substation science inquiries could enhance the students' skills regarding scientific inquiries in rocks. Apedoe (2008) conducted learning programs using geological experiments, and used a supportive guidance strategy for teachers and assistants. The study results show it benefits the development of students' experimental inquiry skills and their geological concepts, and the learning effects were better than that of students who adopted traditional learning methods.

With respect to the learning of other geological themes, Veal & Chandler (2008) suggested instructing students to strengthen the practice of skills in different scientific processes. For example, (1) regarding minerals and rocks, strengthen the practice of "observation, using proper tools, data analysis, and result delivery"; (2) regarding the formation of sandstone from sand, strengthen the practice of "observation, formation hypotheses, and measurement"; (3) regarding the formation of igneous rocks, strengthen the practice of "prediction and formation deductions"; (4) regarding the formation of metamorphic rocks, strengthen the practice of "modeling and observation", and (5) regarding rock identification, strengthen the practice of "observation, data collection and organizing, deduction, and developing indicating items for classification retrieval" etc., thus enhancing students' inquiry skills and improving their inquiry skills in geology.

In addition, with respect to the curriculum and instruction of geology, many researchers have developed new teaching methods and creative teaching activities for geology. The teaching implementation has also achieved quite good effects (Birnbaum, Morris, and McDavid, 1990; Hsu, Wang, and Liang, 2004; Lai, 2010; Semken and Freeman, 2008; Shen, Liu, Yi, Chen, Lin, Chao, and Liu, 2005; Su and Chiang, 2004; Tan, Liu, Mao, and Yang, 1992).

To summarize, the above teaching cases indicate, with respect to the practice of a geology curriculum and instruction, teachers can adopt multiple strategies and methods to carry out their geology teaching and inquiries. Apart from providing opportunities for students to experience and inquire by themselves, the key teaching elements is to inspire students' learning motivation and enthusiasm for geological inquiries using knowledge integration activities, and to cultivate their affection so as to appreciate the beauty of geology, while developing their own concepts of geology and inquiry skills.

Research Method

The study objects were sophomores of an educational university. The studied geology course was called Physical Geology (with experiment session) and was worth four credits (six class hours). The course lasted for one academic year, with two credits (three class hours) per semester. The text book used was Physical Geology by Plummer, Carlson, & McGeary (2007). A total of 31 students (including 11 preservice students) were involved in the study. According to the previous discussions in the literature review, as the content of geology curricula in primary schools is mainly focused on geological concepts, such as minerals, rocks, and changes in the Earth's surface and crust, the design of hands-on geology inquiries for this study mainly focuses on the discussion of minerals, rocks, and geological processes and causes. Second, the literature review also found geology teaching activities should not only pay attention to the learning of geological concepts, but also focus on the development of geology inquiry skills. Therefore, the design of hands-on geology inquiries in this study will strengthen the implementation of hands-on science activities, such as the observation, recognition, and identification of minerals and rocks. Further, with respect to course arrangements, the design of the hands-on geology inquiries integrates important factors, such as class teaching and experimental inquiry activities, with the hope of achieving the maximum promotion of professional growth in the geological knowledge of preservice teachers in colleges using limited teaching time and classes.

To summarize the above considerations, apart from the class teaching based on the physical geology course book by Plummer, Carlson, & McGeary (2007), the key elements of this hands-on geology inquiry scheme for preservice teachers also include an introduction to geology, minerals, igneous rocks, sedimentary rocks, metamorphic rocks and hands-on inquiries, geological processes and the causes, identification tests for minerals and rocks, etc. Second, apart from class teaching and discussion, the implementation of the inquiry scheme also includes conducting five different geological inquiry activities, including "Mineral Bingo", and hands-on inquiries of minerals, igneous rocks, sedimentary rocks, and metamorphic rocks. The latter four activities (10 to 18 types of specimens in each category) use specimens and the learning sheet provided by the Carolina Apparatus Supply Company of the USA (www.carolina.com) to carry out individual hands-on inquiries and identification. Eight specimen identification tests are conducted (10 to 18 types of specimens each time). They are conducted by processing different tasks in various substations, and include four pre-tests and four post-tests. Pre-tests are conducted before the teaching, and the post-tests are conducted two weeks after the teaching. The identification tests for minerals and igneous rocks are conducted in the first semester, and the identification tests of sedimentary rocks and metamorphic rocks are conducted in the second semester. Additionally, there is one off-campus geological field trip to carry out outdoor geological investigations and to collect minerals.

This study collects both quantitative and qualitative data as the main basis for the analyses. The quantitative data are the scores from four specimen identification tests, which are used as the foundation for the analyses. The qualitative data are mainly taken from the learning feedback of the preservice teachers, which are used as the main sources for data analyses. This paper uses *italic* font to present the feedback from preservice teachers as the qualitative data for the analyses. To achieve good reliability and validity for this study, three science education researchers first conducted a triangulation and cross-case inductive analysis on the qualitative data

(Bogdan & Biklen, 1982; Guba & Lincoln, 1999; Patton, 1999; Silverman, 1993, 2000), following which a validity examination was completed to confirm the reliability and consistency of the data analyses and results.

Results and Discussion

Learning performance of the hands-on practice of minerals

With respect to the mineral-themed inquiry and learning, preservice teachers conduct the pre-tests for the mineral identification tests before the teaching, and then conduct the post-tests for the mineral identification tests two weeks after the teaching. A summary of the results of the pre-test and post-test mineral identification tests and the t-test is shown in Table 1.

Table 1. Result of the Pre-tests and Post-tests of the Mineral Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	8	6.38	1.92	7.259	.000***
Post-test	8	12.50	1.41		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (18, 0).

According to Table 1, the scores for the post-tests of the mineral identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and post-tests of the mineral identification tests conducted by the preservice teachers (t = 7.259, $p<.001$). The study results show after receiving hands-on mineral inquiry training, the preservice teachers made significant progress in their learning of minerals and their identification. This result indicates the hands-on mineral inquiry training of this study benefits the learning and understanding of the mineral concepts of preservice teachers.

Learning performance of the hands-on practice of igneous rocks

With respect to the igneous-rock-themed inquiry and learning, the preservice teachers conduct the pre-test igneous rock identification tests before the teaching, and then conduct the post-tests two weeks after the teaching. A summary of the results of the pre-tests and post-tests of the igneous rock identification tests and the t-test is shown in Table 2.

Table 2. Result of the Pre-tests and Post-tests of the Igneous Rock Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	7	4.71	2.14	5.465	.000***
Post-test	8	9.38	1.06		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (10, 0).

According to Table 2, the scores for the post-tests of the igneous rock identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and post-tests conducted by preservice teachers (t = 5.465, $p<.001$). The study results show after receiving hands-on igneous rock inquiry training, preservice teachers made significant progress in their learning of igneous rocks and their identification. This result indicates the hands-on igneous rock inquiry training of this study benefits the learning and understanding of the igneous rock concepts of preservice teachers.

Learning performance of the hands-on practice of sedimentary rocks

With respect to the sedimentary-rock-themed inquiries and learning, preservice teachers conduct the pre-tests of sedimentary rock identification tests before the teaching, and then conduct the post-tests two weeks after the teaching. A summary of the results of the pre-tests and post-tests for the sedimentary rock identification tests and t-test is shown in Table 3.

Table 3. Result of the Pre-tests and Post-tests of the Sedimentary Rock Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	10	6.20	1.40	6.271	.000***
Post-test	11	9.55	1.04		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (10, 0).

According to Table 3, the scores for the post-tests of the sedimentary rock identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and post-tests of the sedimentary rock identification tests conducted by preservice teachers (t = 6.271, $p<.001$). The study results show after receiving hands-on sedimentary rock inquiry training, preservice teachers made significant progress in their learning of sedimentary rocks and their identification. This result indicates the hands-on sedimentary rock inquiry training of this study benefits the learning and understanding of the sedimentary rock concepts of preservice teachers.

Learning performance of the hands-on practice of metamorphic rocks

With respect to metamorphic-rock-themed inquiry and learning, preservice teachers conduct the pre-tests of the metamorphic rock identification tests before the teaching, and then conduct the post-tests two weeks after the teaching. A summary of the results of the pre-tests and post-tests of the metamorphic rock identification tests and the t-test is shown in Table 4.

Table 4. Result of the Pre-tests and Post-tests of the Metamorphic Rock Identification Tests and t-test for Preservice Teachers

test	*N*	*Mean*	*SD*	*t*	*p*
Pre-test	9	4.78	1.86	4.090	.001***
Post-test	11	8.09	1.76		

Note 1: *** means $p<.001$
Note 2: the maximum and minimum values of the mean values are (10, 0).

According to Table 4, the scores for the post-tests of the metamorphic rock identification tests conducted by preservice teachers are significantly higher than those of the pre-tests. The t-test shows there is a significant difference between the results of the pre-tests and the post-tests conducted by preservice teachers (t = 4.090, $p<.001$). The study results show after receiving hands-on metamorphic rock inquiry training, preservice teachers made significant progress in their learning of metamorphic rocks and their identification. This result indicates the hands-on metamorphic rock inquiry training of this study benefits the learning and understanding of the metamorphic rock concepts of preservice teachers.

Qualitative feedback of learning

This study not only analyzes the scores of the four specimen identification tests of preservice teachers, but also collects their learning feedback as sources for analysis. The following are the statements and analyses of the feedback from preservice teachers. Their feedback is presented in *italic* font.

First, taking the hands-on inquiry of minerals as an example, the study asked preservice teachers to answer this question. “Taking quartz and calcite as examples, how do you identify these two minerals?”

Student David answered, “*Drop hydrochloric acid on these two minerals. The one that dissolves is calcite. Or judging from cleavages, calcite has three sets of cleavages. Judging from hardness, quartz is harder than calcite. It is impossible to judge from the color, for both of them are lucent.*” As shown by David’s answer, David has well-mastered the skills for mineral recognition and identification. David is able to use different surface features and properties to effectively distinguish quartz from calcite.

Student Amy answered, “*The hardness index of quartz is 7. It has a hexagonal prism and many colors. The hardness index of calcite is 3. It has three sets of cleavage, is translucent, and will emit CO_2 when you drop hydrochloric acid on it.*” According to Amy’s answer, Amy has also well-mastered the different characters of quartz and calcite to effectively distinguish quartz from calcite.

Student Tony answered, "*The hardness of quartz and calcite differ. Quartz is harder than calcite. Rub the two unknown minerals against each other. The one that scratches is calcite, and the other one is quartz*." According to Tony's answer, Tony has also well-mastered the different properties of quartz and calcite to effectively distinguish them from each other.

Taking the hands-on inquiry of rocks as an example, the preservice teachers were asked to answer this question. "Take gabbro and basalt as an example. How do you identify these two rocks?"

Student Cindy answered, "*Gabbro has obvious joints, while basalt is composed of fine crystals, and its color is darker.*" According to Cindy's answer, Cindy has well-mastered the different features of gabbro and basalt to effectively distinguish them from each other. Linda answered, "*Gabbro has smooth ruptured surfaces and luster, while basalt has neither*." According to Linda's answer, just as Cindy, Linda has also mastered the different features of gabbro and basalt to effectively tell them apart.

Student David answered, "*Both of the two rocks are dark colored or black. Gabbro has shining crystals, while the crystalline particles of basalt are very small*." According to David's answer, David has mastered the skills of identifying igneous rocks, and is able to use the different features of gabbro and basalt to identify them. In addition, David is also able to state some features of gabbro and basalt that are the same.

Student Amy answered, "*Both of them are basic igneous rocks. The crystalline particles of gabbro are larger than 1 mm, and dark in color. The crystalline particles of basalt are smaller than 1 mm, and are dark in color.*" According to Amy's answer, Amy also understands both gabbro and basalt are basic igneous rocks, and is able to effectively identify gabbro and basalt depending on their different features.

Student Tony answered, "*Judging by the weight percentage of* SiO_2*, joints, texture, and colors*." Student Peter answered, "*Compare the sizes of the crystalline particles. Gabbro is a plutonic rock that gradually cools underground. It has larger crystalline particles. On the contrary, basalt cools rapidly, and has smaller crystalline particles*." According to Tony's and Peter's answers, they have both mastered the identification features of igneous rocks.

The third question for the preservice teachers is "How did the pre-tests of the specimen tests influence your identification of minerals and rocks?"

Student Cindy answered, "*I am able to know which of my facts are incorrect or vague in advance. I can write them down when identifying the specimens in the pre-tests, and strengthen my knowledge in class*." According to Cindy's answer, the pre-tests of the specimen inquiry tests can provide Cindy with an opportunity for self-diagnosis, thus strengthening the metacognitive learning, and enhancing Cindy's understanding of minerals and rocks.

Student Mary answered, "*It provides me with an opportunity to review the knowledge I learned in high school. As I haven't seen or touched every specimen before, I am very curious, and more eager to identify minerals and rocks*." Student Amy answered, "*The pre-test applies our knowledge gained in class to the substances (specimens). We may not be able to use this knowledge directly, but it makes us more eager to know what kind of stone it is in the pre-tests*." According to Mary's and Amy's answers, pre-tests can stimulate their interest to explore further and recognize the specimens tested, indicating pre-tests can guide students' learning willingness and strengthen their sense of responsibility toward learning.

To summarize, the feedback from preservice teachers on the study of minerals and rocks show all preservice teachers have well-mastered the features of minerals and rocks, and are able to apply the identification strategies for minerals and rocks. They are able to identify the different minerals and rocks based on different features. Meanwhile, the pre-tests of the specimen identification tests can greatly enhance the willingness and responsibility of preservice teachers toward learning, and promote the learning and understanding of minerals and rocks in the subsequent hands-on inquiry activities by applying proper metacognitive skills. In addition, when comparing the qualitative feedback from preservice teachers regarding the mineral and rock learnings to the scores of the post-tests of the mineral and rock identification tests, it is discovered, after receiving training in the hands-on inquiry activities of geology, the learning performance of preservice teachers in geology is significantly enhanced.

Conclusion

Targeting the implementation of the geology curriculum in colleges, the study aim was to investigate the learning performance of preservice teachers in colleges using hands-on science inquiry strategies and schemes. The study emphasizes the cultivation and training of the hands-on inquiry skills of preservice teachers through implementing a geology curriculum in colleges, thus promoting professional growth in the geological knowledge of preservice teachers. The study results show the scores for the post-tests of the four specimen identification tests are better than those of the pre-tests, indicating the preservice teachers' concepts of minerals and rocks achieved significant growth. Second, the learning feedback from preservice teachers shows preservice teachers have a good level of knowledge regarding geological inquiries. Additionally, the pre-tests of the specimen identification tests can greatly enhance the willingness and responsibility of preservice teachers toward learning, and promote the learning and understanding of minerals and rocks in the subsequent hands-on inquiry activities by applying proper metacognitive skills. These research results indicate the cultivation and training in hands-on geology inquiries can actually enhance the professional growth in the geological knowledge of preservice teachers. Consequently, to summarize, this study believes the cultivation and training in hands-on geology inquiries benefits preservice teachers' learning of geology.

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