Exploration of empathy factors in the science and development of related scales

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Abstract: For a scientific educational approach toward empathy, this study newly defined empathy in science as “empathy with a problematic situation and other people.” In 6 competency frameworks, content related to empathy was extracted, and exploratory factor analysis was conducted through an online survey of 150 teachers. Three factors of empathy with other people and four factors of empathy with the problem situation were extracted. Based on this content, the study modified the Interpersonal Reactivity Index (IRI; Davis, 1980) for use in a scientific situation. This scale was applied to 357 high school students in Korea, and the scale’s validity was confirmed through exploratory factor analysis. Finally, scientific empathy with others was defined as the ability to understand the emotions, thoughts, feelings, and intentions of others and share their viewpoints with accurate emotional responses. And this consisted of perspective-taking in cognitive factor and empathic concern and empathic arousal in emotional empathy. Scientific empathy with the problem situation was defined as an intellectual mechanism deeply involved in the phenomenon of inquiry to clearly understand the scientific problem situation and to share the viewpoint. And this turned out to be perspective-taking and scientific imagination as cognitive factors.

Keywords: empathy; exploratory factor; develop scale; science education

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PUBLIC INTEREST STATEMENT
Recent Social issues are becoming more complex and diverse due to rapid changes in the world. Therefore, society wants to be able to solve these difficulties by collective intelligence rather than solving problems alone. One of the most important strategies for resolving this collaborative problem is empathy. In science education, we can experience the process of solving problems together through empathy among various members. To confirm this in our study, we analyzed previous studies and extracted scientific empathy elements based on the questionnaire of science teachers. Through this, we developed a scale of scientific empathy and applied it to high school students to confirm its validity. Hence, it is our hope that this article will be the cornerstone of studying empathy as a learning strategy in science.
1. Introduction

In modern society, an imperative task is to collect information amid a knowledge information society, critically analyze and integrate such data, and improve the creativity and problem-solving ability to create information (Runco, 2004). In education, the teaching of creativity is a key factor that affects individuals and national competitiveness (MEST, 2011), and the development of systematic and diverse educational programs to raise creativity has attracted much interest (Renzulli & Reis, 1997). Therefore, talented people who demonstrate the creative ability to solve problems for creating knowledge are crucial to society. To cultivate such talent, the learning environment at schools must also stimulate creativity (Lee & Lee, 2007).

Creative problem-solving in science education seeks to discover new and proper solutions to problems based on basic knowledge of science, inquiry processing skills, and scientific creativity factors (Cho, Choi, Chae, Sung, & Suh, 2000). The tendency to think of creativity merely as an individual’s unique ability has remained largely in primary and secondary education (Jeong & Cho, 2012; Park & Kang, 2011). For example, a study analyzed the effects of the model on the development of student creativity after revising and supplementing the creative problem-solving model according to the content of a science subject in individual personality, intelligence, cognitive style, and synchronization (Joo, Chung, & Pyo, 2011; Kim, Ha, Park, & Kang, 2008; Kim, Jeon, & Park, 2002; Yoon & Woo, 2011). Based on previous studies on the effects of group tasks among group members with individual characteristics, many groups failed to actualize the effects of group creativity (Mesmer-Magnus & DeChurch, 2009; Stasser & Titus, 1985; Van Ginkel & Van Knippenberg, 2008). In other words, contrary to general expectations, the effect of group task performance is not superior to that of individual performance but often is adversely affected. The results of this research are not synergistic because they comprise a group of individuals who solve problems or work. To gain meaning beyond the sum of individual performances, various strategies and requirements are needed (Sawyer, 2007). In addition, recognition of a need for satisfaction is important. So, to create synergy by drawing the potential of each member in the problem-solving process of science education, harmonious actions from cognitive and positive aspects are important. In this case, the use of understanding can help redefine problems, and empathy can be anticipated as a strategy when devising a framework for existing problems and solutions (Ko, 2013).

In this sense, empathy is the cognitive and emotional response to other people’s emotions and situations (Davis, 1980; Hoffman, 1984). The shared goals among all members for effective cooperative interactions for collaborative problem-solving are one of the most useful methods to support and promote understanding and trust between people of various backgrounds and talents (Kim et al., 2012; Martin, 2010; Park, 2010). In addition, meaningful communication among group members for collaborative interaction starts from actively understanding and accepting the differences among members (Egan, 1990). This is the crucial and fundamental element in such communication (Eisenberg & Miller, 1987). Sawyer (2007) suggested that identifying the cause of a problem can lead to a more creative solution. In this case, sensitivity to the problem is related to cognitive empathy which recognizes the situation from other people’s viewpoint and finds the problem based on the concern and consideration of others that can also be related to emotional empathy (Howe, 2012; Park, 2004). The constructivist scholar Seymour Papert said that to gain an understanding of learning is to enter the situation and that there is no empathy without immersion, no feeling of another person without empathy, and no way to internally grasp the situation without stressing the importance of immersion and empathy in learning (Ackermann, 2010). After all, empathy is not only an emotional aspect that lets you control your emotions and increase your pro-social behavior, but it is also the cognitive areas that help you understand learning and develop creative thinking (Lee & Chin, 2014). And sensibility or empathy can also help you recognize problems from new perspectives, beyond stereotypes, and figure out solutions (Lee, 2015).

Currently, science education sees scientific literacy as “the ability to participate in science-related issues as a reflective citizen with the idea of science” (OECD, 2013, p. 7). Science is a social discipline, and students should be influenced by society through science and should improve their literacy. However, as you know, previous science education was interested in
accumulating knowledge to train students as science experts rather than education for all people (Osborne, 2013). However, the scientific thinking process of scientists has been identified as being formed within a group (Dunbar, 2000). In this way, science education should improve scientific literacy through social competence, and empathy cannot help but occupy an important position in science education. One scholar even insisted on the necessity of participation and empathy even in the era of modern science, where traditional scientific methods are the mainstream. Goethe said, “The power of thought is activated at the moment of unification with the object, and then the thoughts are not separated from the object,” adding that true insight is obtained not from vague observations but by deeply participating in exploratory phenomena (as cited by Rifkin, 2009). Kohut (1975) argued that the scientific method is experience-distant and that there is distance from the actual observation. If empathy is applied to science as an observation tool, it increases the depth and breadth of research conducted based on scientific principles. Moreover, people should pursue empathic science as well as scientific empathy. This case in point means that empathy leads to new discoveries and insights about nature that cannot be imagined by previous objectives and value-neutral scientific methods and shows the importance of empathic approaches toward science. Therefore, it is necessary to identify scientific empathy factors in science education.

Yet, previous research on empathy mainly has focused on counseling and psychotherapy, and only since the 1990s have studies on empathy training programs been done (Park, 2004). Recent years have seen published literature linking empathy with specific subjects, but such subjects have mainly been literary, social, and artistic (Lee & Chin, 2014). Few examples exist of linking scientific subjects with empathy. Science education requires discussion of not only creativity and problem-solving but also empathy. Many measures have also sought to gauge empathy including Davis’s interpersonal reactivity index (IRI), the Hogan empathy scale, and the Mehrabian and Epstein’s (1972) emotional empathy scale (Hojat et al., 2002). The most widely used scale to measure empathy to date is the IRI (Albiero, Matricardi, Speltri, & Toso, 2009). Although there have been studies to confirm the educational effects of empathy using this scale, it does not reflect the nature and educational purpose of the subject applied. The IRI scale is a model of empathy that focuses on the psychological side. Recently, the importance of empathy has been mentioned in terms of scientific literacy (Dunbar, 2000; Osborne, 2013), but there have been few studies that measured or analyzed it with objective data. Especially, there are not enough previous studies that have developed a test or scale. In this regard, extracting elements of empathy that are compatible with the characteristics of science curriculum and developing them as a scale would have great significance in the development of science education.

This study sought to identify empathy in science through a literature review and an assessment of what factors that are related to empathy as well as develop an empathy scale that is usable in a science class based on the Davis’s IRI scale for the evaluation of validity.

2. Methods
The overall research procedure for developing empathy in science education and exploring the related components is shown in Figure 1.

First, based on the definition of empathic science per counseling and psychology, the study renewed the definition of empathy in science education. Through this analytical framework, a survey was conducted on empathy components. For this purpose, the generic model overlay method (Dubois, 1993), whose analysis is based on the verified model when no information on the model’s competence can be identified, and the Critical incident technique (Flanagan, 1954), which collects and analyzes events consisting of real actions in certain situations, were applied. After that, based on the explored variables, empathy was newly classified from the standpoint of science education. The study eventually developed an empathy scale usable in a scientific situation by revising the factor extraction and items based on a group interview (Lee, 2007) of scientific experts. The specific research methods of this study and its content are as follows.
2.1. Definition of empathy in science education

This study analyzed how empathy was defined by reviewing the literature on empathic science and how the constituents of general empathic science were made. To apply empathy to science education, case studies were analyzed. Table 1 shows empathy in science based on the analysis of the behavioral characteristics of crises and specific problems from the autobiographies, homographs, and research papers of leading scientists in each field.

The necessity of empathy in science was confirmed by the importance of the empathic approach found by a review of scholars’ literature. Finally, empathy in science education was newly defined.
by comparing and analyzing empathy’s characteristics in previous studies and in case studies on scientific empathy published in the scientific literature.

2.2. Exploring factors behind empathy

After defining empathy, this study selected six competency analysis frameworks which included “Future Society’s Core Competence of Koreans” (Yang & Kang, 2016). As a method to extract the variables, the generic model overlay method and critical event analysis were used. Through this, the variables were extracted, and the validity of the extracted variables was verified by consultation with science education experts (Table 2).

By analyzing the critical event technique, variables related to scientific empathy not extracted or confirmed by the generic model overlay method were further searched for to raise the validity. And the results were expressed as behavioral indicators related to empathy in science education. Researchers tried to extract the perceptions of science teachers from their behavioral indicators and developed them into a questionnaire. The questionnaire on empathy was written in Korean, and it was given through an online survey (conducted from April 19 to 19 May 2016) to science teachers and pre-teachers nationwide. Among them, 150 questionnaires, excluding one that was not correctly filled out, were used in the exploratory factor analysis. When extracting survey subjects, we selected participants who were elementary school teachers from one area through a simple random sampling among teachers who agreed to participate in this study. The survey also targeted teachers in charge of gifted classes and science education at elementary schools in the area. Additionally, we selected participants who were middle and high school teachers from four regions in the South Chungcheong Province by Stratified Sampling and randomly selected nine schools (middle school, eight; high school, one) from each region. Teachers teaching science at each school were encouraged to respond individually, and the survey links were shared and recalled. This analysis of the collected data had factors extracted by common factor analysis that included communality on the diagonal of the correlation matrix; the factors were found based on the attributes of the variables’ structure. The factor rotation method used the direct oblimin method, which rotates oblique factors, to maintain the inter-factor association.

2.3. Development of the empathy scale

The first and second studies defined empathy in science education and explored empathy variables. Based on the questionnaire, data were collected and analyzed on empathy in science education. The students were then classified according to the IRI framework based on the findings, and an empathy scale usable in a classroom situation was developed. The detailed procedure for this is shown in Figure 2.

Through the translation of cognitive and emotional empathy and the scale items of Davis (1980), the study created empathy scale items and then developed empathy scale items for empathy with others and problematic situations based on that information to apply to scientific teaching

| Table 2. Framework chosen for the analysis of empathy related to science |
|-----------------------------------------------|-----------------------------------------------|
| Competence framework                        | Agency (Issue year)                           |
| Future society’s core competence of Koreans | Korea Institute of Curriculum and Evaluation (2008) |
| Assessment and Teaching for twenty-first century Skills (2012) | ATC21s (2012) |
| Competence at work: model for superior performance | Spencer and Spencer (2008) |
| Clustering competence in emotional intelligence: insights from the emotional competencies inventory (ECI) | Boyatzis, Goleman, and Rhee (2000) |
| The definition and selection of key competencies (DeSeCo) | OECD (2013) |
| P21 framework | Trilling and Fadel (2009) |

Note. Future society’s core competence of Koreans as cited by Yang and Kang (2016).
Because academic aptitude is decided at high school in Korea, we think that it is appropriate to apply a scientific empathy scale reflecting academic characteristics to first-year high school students. The subjects were 357 sophomores at Chungcheong High School (189 male and 168 female); the data on 355 respondents who responded correctly were analyzed. The Davis’s IRI (1980), which is often used in general empathy tests, is based on a multidimensional view of empathy. This study only reported on data from consenting participants. The index comprises four subscales, among which perspective-taking and fantasy are related to cognitive empathy, and empathetic concern and personal distress are related to affective empathy. The number of questions per sub-scale was 28 by 7 and consisted of a Likert-style, 5-point scale. The reliability of perspective-taking was (M: .71; F: .75); fantasy was (M: .78; F: .79); empathy concern was (M: .68; F: .73), and personal distress was (M: .77; F: .75). To get these results, SPSS (IBM/Seoul/Republic of

| Stage | Content                                                                 | Method                                                                 |
|-------|-------------------------------------------------------------------------|------------------------------------------------------------------------|
|       | **Classification of scientific empathy factors**                        | • Exploring empathy components via research results 1 & 2, literature    |
|       | • Classify empathy areas & sub-elements extracted according to IRI       | • Science education professionals & workshops                           |
|       | **Development of the scientific empathy scale**                         | • Adoption of the Davis (1980) empathy scale                            |
|       | • General empathy scale                                                 | • Science education professionals & workshops                           |
|       | • 1st: Developing items for the scientific empathy scale                 | • Science education experts’ workshop                                   |
|       | • Develop items according to scientific situations based on the general empathy scale |                                                                       |
|       | • 2nd: Developing questionnaires                                         | • Kim (1997) Exploring empathy ability test sites including scale       |
|       | • Modifying & deleting relevant messages adding new questionnaire for the 1st developed items for the scientific empathy scale | • Science education experts’ workshop                                   |
|       | • Input of secondary scientific empathy scale                            | • Student survey                                                        |
|       | • Analysis of the survey data                                           | • Exploratory factor analysis                                          |
|       | **Final scientific empathy scale**                                       | • Science education experts’ workshop                                   |
|       | • Final empathy scale for scientific situations                          |                                                                       |
Korea) was used to confirm the reliability of the data emerging from the questionnaire and to identify emergent factors.

3. Results

3.1. Definition of empathy in science education

3.1.1. Empathy in scientific cases

To introduce empathy in science education, a literature study was conducted on how empathic perspectives affect scientific development. The analysis results for the use of empathy in scientific problem-solving by scientists are as follows. First, American biologist James Watson’s autobiography showed empathy for other people in a collaborative problem-solving situation.

What Watson said about the meeting with British colleague Francis Crick.

It was real luck finding someone who knew DNA was more important than protein,

Watson also talked about the fortieth anniversary of the discovery of the double helix, emphasizing the importance of relationships with peers in scientific research.

You have to do what you like and hang out with scientists who can give and receive intellectual help. One reason competitors did not get to the double helix before us was because they were isolated. (Watson, 1968)

The science historian Grievin said the following about Watson and Crick: “The greatest thing they had was to take each other’s ideas and try to understand what the other person meant in detail, and if necessary, break down and reassemble the DNA model” (As cited in Jo, 2006). As seen in the example above, understanding and agreeing with each other’s emotions by forming a consensus is crucial in collaboration, and empathy is a key factor in promoting scientific collaboration.

In the process of scientific research, empathy is not only empathy for others like that shown above, but also empathy for the subjects of a study done on a problematic situation. Great scientific discoveries were made through constant interest and empathy for a subject or problematic situation. The following are examples of such empathy seen throughout the history of science.

Einstein had a kind of “accidental experiment:”

He imagined himself to be a photon moving at the speed of light. “Imagine what he saw and felt as a photon, then he assumed the role of another photon, and imagined what he experienced in the role of the first photon.”

(Root-Bernstein & Root-Bernstein, 2007, p. 23)

Einstein imagined himself as a photon and looked at the universe from a photon’s perspective. Drawing on the idea of a photon moving at the speed of light, he setup a number of hypotheses through an imaginative experiment of what is seen in the photon’s position and proposed a photon model in which light consists of particles.

Many scientists say their feelings lead to a logical concept, and creative thinking and expression come from intuition and emotion. Bernstein said such feelings and intuition are not obstacles to but rather a source of and basis for rational thinking. The French philosopher Henri Bergson said the most important insights were made only through emotions and that absolute reach was only possible through “intuition.” Additionally, intuition can also be called empathy, he added, and by using it, people can move themselves into the interior of an object with attributes that cannot be expressed in the words of the
object (as cited in Root-Bernstein & Root-Bernstein, 2007). Another philosopher, Karl Popper, saw the most useful way to gain new understanding of empathic intuition as “going into a problem and being part of it” and saying “I am not myself” (as cited in Root-Bernstein & Root-Bernstein, 2007).

3.1.2. Empathy in science education
Defining empathy in science education can largely be looked at in two ways.

First, empathy for others is analyzed from the viewpoint of science education that emphasizes cooperation and communication for collaborative problem-solving. The goal of science education is based on the ability to communicate about science, scientifically solve problems, and cultivate scientific literacy to make scientific decisions (National Research Council, 1996). To equip students with scientific communication, problem-solving, and decision-making skills, science education should teach the nature of science (Yore & Treagust, 2006); that is, the process of collaborating with scientists (Ryan & Aikenhead, 1992) that also includes scientists negotiating scientific knowledge (Yerrick & Roth, 2005). Thus, in science class, students should cooperate like scientists to experience and discover scientific knowledge through collaborative research (Osborne, Erduran, & Simmon, 2004). From the aforementioned perspective of science education, scientific communication as a core competency of the revised science curriculum of 2015 is mentioned. As a sub-element, scientific communication is based on empathy for and understanding others, as well as helping others to communicate with each other.

As the constructivist scholar Seymour Papert (1980) insisted on entering the context to gain understanding in learning and emphasized immersion and empathy in learning, empathy can be a key element to solving problems through further immersion in problematic situations; empathy can be identified and applied to problematic situations even in a classroom.

Empathy can be seen to influence more concentrated experiences in problematic situations, as shown in a study by Yeo (2011), which confirmed a correlation between empathy and flow. To define empathy in science, the definition of the elements of empathy is needed as well as for empathy for others and for problematic situations.

3.1.3. The meaning of empathy in a scientific situation
To identify the attributes of empathy in science, this study defined and categorized empathy in science education through previous research analyses and defined empathy based on the definitions commonly used in psychology. Through the definition that empathy's attributes are divided into cognitive factors, that empathy understands and accepts others' roles and perspectives as if they were oneself (Shin, 1994), and emotional factors constituting feelings of empathy with different orientations and interest in the unhappiness of others (Davis, 1980), this study examined scientific empathy through the general definition of a multidimensional composite concept. As previously seen, empathy in the process of creative problem-solving based on collaboration in the context of the teaching and learning of science should be discussed not only through empathy for others but also for problematic situations. This study also studied empathy for other people as well as for a scientific situation by transforming the definition and sub-elements of empathy as discussed now. As a result, scientific empathy is defined as aspects for others and for problematic situations.

**Scientific empathy with others:**

Ability to understand the emotions, thoughts, feelings, and intentions of others and share their viewpoints with accurate emotional responses.

**Scientific empathy with problem situations:**
It is deeply involved in the phenomenon of inquiry as an intellectual mechanism exercised to clearly understand the scientific problem situation and to share the viewpoint.

In a scientific context, emphasizing with others has led to the definition of Chandler et al. (1974) among diverse scholarly definitions of empathy, and empathizing with problematic situations has been redefined based on scholarly claims for the need for empathy in scientific cases and science education. Scientific Empathy with problem situations was defined as deeply participating in the phenomenon of inquiry as an intellectual mechanism that clearly understands the situation and shares viewpoints. It also helps make scientific inferences such as acceptance and observation of various viewpoints, hypothesis setting, experimentation, verification, and the ability to think productively and to understand new ways through scientific knowledge based on the process of feeling emotional about such knowledge. This study explored scientific empathy factors based on the classification and definition of empathy in science.

3.2. Exploring empathy factors

3.2.1. Extracting associated components

In accordance with the definition of empathy in a scientific situation, we extracted all variables that are judged to be adequate from a total of six capacity analysis frameworks which included “Future Society’s Core Competence of Koreans.” Part of the core competency extraction process related to scientific empathy with others is shown in Table 3.

In the first analysis, a total of 42 variables, which are considered to be related to scientific empathy with a problem situation, and 40 variables, which are considered to be related to scientific empathy with others, were extracted through the competence analysis framework. Then, through a seminar, we conducted a second review, comparing and analyzing the extracted competencies with one science education expert and two science education pre-master teachers. Through this consultation with science education experts, we were able to sort out the redundant and integrative variables. Finally, this study extracted 40 variables with the generic model overlay method (10 variables related to scientific empathy with others and 30 related to scientific empathy with problem situations). Through the important event technique, we analyzed the behavioral characteristics of scientists in various fields, such as autobiographies and research papers, in crisis or specific problem situations. As a result, five competencies that were not extracted by the general model overlay method were found to be additional variables of scientific empathy in problem situations. Finally, we extracted 45 variables related to empathy in science education.

Based on the results, the interview questionnaires for the focus group were constructed, and the validity of the extracted variables was verified. Afterwards, a focus group interview (Lee, 2007) followed consisting of one science education specialist, four science teachers, and two teachers in training. These opinions were combined to reach a common opinion. Thus, the study organized 9 variables related to scientific empathy with others and 21 variables related to scientific empathy with problem situations, based on the IRI scale (Table 4).

3.2.2. Surveys for exploring scientific empathy factors (Subject: Science teachers)

To distinguish the empathy factors related to a scientific situation, online questionnaires were given to science teachers and those training to be teachers throughout Korea. The first four items of the questionnaire were related to personal information, and the fifth and sixth items assessed the degree of empathy and relevance in each item and in science by using a 5-point Likert scale.
### Table 3. Examination of scientific empathy components with others through a generic model overlay method (First)

| Competence framework | Future society’s core competence of Koreans | Assessment and Teaching for twenty-first century Skills | Competence at work: model for superior performance | Clustering competence in emotional intelligence: insights from the emotional competencies inventory (ECI) | The Definition and Selection of Key Competencies (DeSeCo) | P21 framework |
|----------------------|-------------------------------------------|--------------------------------------------------|---------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------|---------------|
| Core competency      | Understanding and respecting others       | Interpersonal understanding                      | Empathy                                           |                                                                                                  |                                                                 | Interact effectively with others          |
|                      |                                           | Customer service orientation                     |                                                   |                                                                                                  |                                                                 |                                           |
| Collaboration        | Collaboration                              | Teamwork & cooperation                           | Cooperate                                         |                                                                                                  | Work creatively with others                | Work effectively in diverse team          |
|                      |                                           |                                                   |                                                   |                                                                                                  | Collaborate with others                    |                                           |
| Conflict management  | -                                         | -                                                | Conflict management                               | Manage and resolve conflicts                                                                     | -                                          |                                           |
| Relationship formation| -                                         | Relationship building                            | Building bonds                                   | Relate well to others                                                                           | -                                          |                                           |
|                      |                                           | Flexibility                                      |                                                   |                                                                                                  |                                            |                                           |
| Community consciousness| Citizenship-local and global              | Organizational awareness                         | Organizational awareness                         | Act within the big picture                                                                      | -                                          |                                           |

Note. Future Society’s Core Competence of Koreans as cited by Yang and Kang (2016).
| | Scientific empathy with others | Scientific empathy with problem situations |
|---|---|---|
| **Generic model overlay method** | Extraction of 10 variables | Extraction of 30 variables |
| | Understanding & respect for others, teamwork & cooperation, conflict management, relationship molding, leadership, development of others & growth, community consciousness, international understanding, speaking, listening | Fluency, flexibility, originality, elaboration, analogous sex, sensitivity, openness, independence & challenge concentration, spontaneity, innovative performance, adaptation to change, flexibility, problem recognition, search for & implementation of solutions, conceptual, analytical & critical thinking, metacognition, judgment & decision making, thinking as a whole, information collection & analysis, achievement orientation, accurate self-assessment, self-confidence self-regulation, self-identification, self-directed learning ability |
| **Critical incident technique** | Extraction of 30 variables |  |
| | Intuitive understanding, commitment to problems, organic feeling & empathy, divergent thinking & free reminiscence, interest in variety of things |  |
|  |  |  |
| **Focus group interview** | Organized into 9 variables | Organized into 21 variables |
| | Understanding and respect for others, teamwork & cooperation, conflict management, relationship molding, leadership, community consciousness, international citizenship, speaking, listening | Flexibility, analogous sex, sensitivity, openness, spontaneity, intuitive understanding, divergent thinking, variety of things for attention, problem recognition & commitment to issue, empathy, search for solutions, conceptual, analytical & critical thinking, metacognition, judgment & decision making, thinking as a whole, information gathering & analysis, accurate self-assessment |

*Note: Generic model overlay method (Dubois, 1993), critical incident technique (Flanagan, 1954), Focus group interview (Lee, 2007)*
3.2.2.1. Analysis of factors related to scientific empathy for others. The mean and standard deviation of the questionnaire items for science teachers on factors related to scientific empathy for others were mostly related to empathy with other people with an average score of 4.0 or higher. Items 5 (2), 5 (7), and 5 (12), however, had lower average scores compared to the others. The results of this study are summarized as follows (Table 5).

First, the questionnaire survey was conducted with the 5 (12) items except for 5 (2) and 5 (7). The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy for the appropriateness of a standard formation indicates whether the overall correlation matrix is suitable for factor analysis for which the value is 0.847 or higher than the standard value of 0.50. And Bartlett’s sphere formation test shows the overall significance of all the correlation values in the correlation matrix; thus, if the value is significant, the data could be used in the factor analysis. In this study, the probability of significance of Bartlett’s sphere formation test was less than 0.01; therefore, the correlation between the variables was significant, and the data were appropriate for use in the factor analysis. Among the three factors related to scientific empathy for others, reliability was 0.813 for the first, 0.810 for the second, and 0.763 for the third. The result of the correlation analysis for all three factors was confirmed as significant. Each factor had a correlation coefficient of 0.5 or more with a high correlation (Table 6).

Table 5. Exploratory factor analysis of scientific empathy for other people (Subjects: Science teachers)

| Question no. | Factor 1 | Factor 2 | Factor 3 | Cronbach’s α |
|--------------|----------|----------|----------|--------------|
| ques_5(4)    | .550     |          |          | 0.813        |
| ques_5(5)    | 1.006    |          |          |              |
| ques_5(6)    |          | .442     |          | 0.810        |
| ques_5(8)    |          | .528     |          |              |
| ques_5(9)    |          | .584     |          |              |
| ques_5(10)   |          | .719     |          |              |
| ques_5(11)   |          | .692     |          |              |
| ques_5(12)   |          | .537     |          |              |
| ques_5(11)   |          | −.420    |          | 0.763        |
| ques_5(13)   |          | −.482    |          |              |
| ques_5(14)   |          | −.599    |          |              |
| ques_5(15)   |          | −.749    |          |              |
| ques_5(16)   |          | −.655    |          |              |

Kaiser-Meyer-Olkin Measure of Sampling Adequacy of standard formation suitability 0.847
Bartlett’s sphere formation test
Approximate chi square 790.432
Degree of freedom 91
Probability of significance .000

Table 6. Correlation of Factors 1, 2 & 3 (Subjects: Science teachers)

| Variable | Mean  | Standard deviation | Correlation Factor 1 | Correlation Factor 2 | Correlation Factor 3 |
|----------|-------|--------------------|-----------------------|-----------------------|-----------------------|
| Factor 1 | 4.313 | 0.013              | 1                     | .651**                | −.543**               |
| Factor 2 | 4.118 | 0.108              | .651**                | 1                     | −.516**               |
| Factor 3 | 4.299 | 0.091              | −.543**               | −.516**               | 1                     |

**The correlation coefficient is at the 0.01 level (both sides)**
3.2.2.2 Analysis of factors related to scientific empathy with problem situations. Most of the questions in the questionnaire on factors related to scientific empathy with problem situations were answered with an average score of 4.0 or more, which is related to scientific empathy for the research subjects. In scientific empathy with problem situations, the deviation among the items was larger than that of scientific empathy for others. Thus, the results of the discussions with scientific education experts were analyzed as follows, excluding questions 6 (6), 6 (8), and 6 (20), which had an average score of 3.9 or less. Because the KMO is 0.899, and Bartlett’s sphere formation test shows .000, the data from this area are also appropriate for the factor analysis (Table 7).

Among the five factors related to scientific empathy with problem situations, reliability was 0.867 for the first, 0.860 for the second, 0.875 for the third, 0.584 for the forth, and 0.784 for the fifth factor. The results of the correlation analysis for Factors 1, 2, 3, and 5 were confirmed as significant. Factor 3 has a correlation coefficient of more than 0.5 for Factors 1, 2, and 5 and a high

| Question no. | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Cronbach α |
|--------------|----------|----------|----------|----------|----------|------------|
| ques_6(21)  | .479     |          |          |          |          | 0.867      |
| ques_6(22)  | .515     |          |          |          |          |            |
| ques_6(23)  | .462     |          |          |          |          |            |
| ques_6(28)  | .760     |          |          |          |          |            |
| ques_6(29)  | .972     |          |          |          |          |            |
| ques_6(30)  | .461     |          |          |          |          |            |
| ques_6(1)   | .396     |          |          |          |          | 0.860      |
| ques_6(2)   | .331     |          |          |          |          |            |
| ques_6(4)   | .333     |          |          |          |          |            |
| ques_6(7)   | .501     |          |          |          |          |            |
| ques_6(10)  | .808     |          |          |          |          |            |
| ques_6(11)  | .899     |          |          |          |          |            |
| ques_6(12)  | .527     |          |          |          |          |            |
| ques_6(18)  | −.540    |          |          |          |          | 0.875      |
| ques_6(19)  | −.932    |          |          |          |          |            |
| ques_6(24)  | −.498    |          |          |          |          |            |
| ques_6(25)  | −.422    |          |          |          |          |            |
| ques_6(26)  | −.518    |          |          |          |          |            |
| ques_6(27)  | −.485    |          |          |          |          |            |
| ques_6(13)  |          | .433     |          |          |          | 0.584      |
| ques_6(14)  |          | .306     |          |          |          |            |
| ques_6(3)   |          |          | .386     |          |          | 0.748      |
| ques_6(15)  |          |          | .393     |          |          |            |
| ques_6(16)  |          |          | .611     |          |          |            |
| ques_6(17)  |          |          | .529     |          |          |            |
| ques_6(31)  |          |          | .527     |          |          |            |

Kaiser-Meyer-Olkin Measure of Sampling Adequacy of standard formation suitability 0.899
Bartlett’s sphere formation test
Approximate chi square 2,176.953
Degree of freedom 325
Probability of significance .000
correlation with each factor. On the other hand, Factor 4’s reliability constant was too low; therefore, it was excluded from the question (Table 8).

### Table 8. Correlation of factors 1, 2, 3, & 5 (Subjects: Science teachers)

| Variable | Mean | Standard deviation | Correlation |
|----------|------|-------------------|-------------|
|          |      |                   | Factor 1    | Factor 2 | Factor 3 | Factor 5 |
| Factor 1 | 4.026| 0.054             | 1           |         |          |          |
| Factor 2 | 4.084| 0.062             | .427**      | 1       | -.525**  | .374**   |
| Factor 3 | 4.016| 0.082             | -.525**     | -.675** | 1        | -.569**  |
| Factor 5 | 4.028| 0.043             | .374**      | .489**  |          | 1        |

**The correlation coefficient is at the 0.01 level (both sides).**

3.2.2.3. Interpretation of the results of the exploratory factor analysis. Based on the questionnaires given to science teachers, three items on scientific empathy for others and four factors related to scientific empathy with problem situations were extracted. The factors explored through consultation with science education experts were defined based on the common factors of each question. Factors related to scientific empathy for others were “sense of community,” “cooperative interaction,” and “understanding of others.” Factors related to empathizing with problem situations were “searching for and understanding the problem,” “scientific imagination,” “searching for solutions,” and “commitment to the problem and empathy.” Table 9 compares the results of the exploratory factor analysis with existing scientific empathy factors.

Based on this analysis, affective elements such as community consciousness and interpersonal abilities as well as cognitive aspects were deemed necessary for empathizing with others in a science class. Therefore, when introducing the empathy-based instructional model into the educational curriculum for science, an empathy strategy is needed to develop a cooperative problem-solving ability by building positive relationships and efficient communication to improve empathy for others. Moreover, to improve the empathic ability by applying it to a science class, an efficient and practical strategy is needed for raising empathy in a class related to problem recognition and a solution plan.

### Table 9. Comparison of existing and extracted scientific empathy factors

| Domain         | Existing empathy factors | Extracted scientific empathy factors |
|----------------|--------------------------|-------------------------------------|
|                | IRI (Davis, 1980)        | Scientific empathy for others        |
| Cognitive      | Perspective-taking,      | Understanding others                 |
|                | Fantasy                  | Explore & understand problem,       |
|                |                          | scientific imagination,              |
|                |                          | explore solution, commitment &      |
|                |                          | empathy for problem                  |
| Affective      | Empathic concern,        | Sense of community                   |
|                | Personal distress        |                                     |
|                |                          | Cooperative interaction              |

3.3. Reinterpretation of the empathy factor for scale development

A reinterpretation of the scale based on the emotional factors (cognitive and affective empathy) used in empathy is needed to develop scientific empathy factors appropriate for a scientific situation. At this stage, the emotional factor extracted from the results of the questionnaires for science teachers should be applied as a scale. Davis’s IRI measures cognitive and affective empathy and has questions about empathy for others. To measure the empathy factor vis-à-
vis problem situations in previous research on the use of empathy in science, this area was newly added to the Davis’s empathy scale framework in this study. A scale was devised to measure cognitive empathy through comparison with the behavioral indicators presented in the exploratory factor analysis. Finally, in science education, the scientific empathy scale was categorized as empathy for other people, including IRI’s cognitive and emotional empathy and that with problem situations. In addition, fantasy, classified as a sub-conscious of cognitive empathy in IRI, is difficult to see as a cognitive element in a scientific situation. Because fantasy here means the degree of imagining oneself as a fictional character or emotion in a movie, play, or book, it thus was excluded from other people’s empathy. Therefore, these questions were included as a cognitive component of empathy with problem situations.

In defining sub-elements corresponding to each area, this study used as a basis the emotional factor extracted from the questionnaires for science teachers and related behavioral indicators. Fantasy, a sub-element of cognitive empathy, is summarized as scientific imagination through immersion and empathy about the problem and extracted via scientific empathy with problem situations. Additionally, personal affection, a sub-element of emotional empathy, is defined as empathic awakening for expressing not only the pain but also the emotions of other people based on the results of empirical empathy.

3.4. Input and analysis of the scientific empathy scale

3.4.1. Development of the scientific empathy scale

With Davis’s IRI (1980) as a framework derived from common empathy items, the question of empathy and the scientific empathy scale with others and problems situations were developed and modified to fit the scientific context. To verify their feasibility, three meetings were held, one for science education specialists and two for teachers possessing a Master’s in science education. The final scale was completed by revising the items.

3.4.1.1. Development of the scientific empathy scale items according to the scientific situation (1st). Davis’s IRI (1980) is based on a multidimensional view of empathy and consists of four subscales. They are the perspective-taking scale (PT), which measures “the acceptance of others perspective,” the fantasy scale (FS), which measures “the tendency to engage in novels or movies,” the empathic concern scale (EC), which measures “tendency of compassion, warmth and interest in others suffering from negative experiences,” and Personal distress scale (PD), which measures “tendency toward anxiety and inconvenience when seeing negative experiences of others.” This scale was translated as a framework, and sub-questions were developed by applying the scientific empathy factors derived from the multidimensional definition of scientific empathy and from the exploratory factor analysis.

When developing these items, this study used an empathic area classification modified and supplemented to fit the given scientific situation (Table 9). As for the scale for “scientific empathy for others,” the subscales of Davis’s (1980) empathy scale were based on general empathy items related to perspective-taking, empathic concern, and personal distress. The scale for “scientific empathy with a problem situation” focused on developing items by applying the science class situation based on the PT and fantasy aspects of the sub-factors of the Davis’s (1980) empathy scale.

For example, when IRI’s PT item was applied (e.g. “I try to think from his position for a while when I’m angry at my friend”) to “scientific empathy for others” (e.g. “I try to think from his position for a while when I’m angry at a friend during a scientific experiment”), this study introduced the situation of the experiment and revised the question. In “scientific empathy with problem situations,” the situation was changed when a subject was angry because of a friend into a frustrating situation when conducting an experiment in a problematic situation. Based on the tendency to take the position or viewpoint of the subject or problematic situation in a study, the
item was modified as follows: “I don’t get the results of the experiment, so I’ll try to reconsider the experiment when I’m frustrated.”

3.4.1.2. Correcting and supplementing questions (Second). In developing the items of the second scientific empathy scale, several reverse grading items of EC and fantasy were modified to the point of settlement through discussions with the expert group. In emotional awakening, items with duplicate content or meanings were revised and deleted. Empathic arousal, a sub-element of empathy for others, was based on personal distress per the empathy scale of Davis (1980). Yet, in the sense that they know not what to do, five of the seven items were deleted, and just two representative items were left. Based on the definition of empathic arousal, this study also referred to and analyzed the test of Kim (1997), Park (1997) and Moon (1999) by selecting items and reconstructing them.

3.5. Analysis of the empathy scale questionnaire

3.5.1. Results of the exploratory factor analysis of the scale for scientific empathy for others
For each item of the developed scale for scientific empathy, exploratory factor analysis was conducted by giving two questionnaires to each student. Table 10 shows the analysis results by categorizing the factors of the 17 items consisting of elements related to scientific empathy for others.

The KMO Measure of Sampling Adequacy of standard formation suitability was 0.886, which was higher than the standard value of 0.50; thus, the data were suitable for factor analysis, and the significance probability of Bartlett’s spherical test was less than 0.01. Therefore, the correlation

| Question no. | 1  | 2  | 3  | 4  | Cronbach’s α |
|--------------|----|----|----|----|--------------|
| Q1(7)        | -605 |    |    |    | .744        |
| Q1(8)        | -523 |    |    |    | .736        |
| Q1(21)       | -475 |    |    |    | .736        |
| Q1(30)       | -373 |    |    |    |             |
| Q1(31)       | -784 |    |    |    |             |
| Q1(17)       | -383 |    |    |    | .548        |
| Q1(26)       | -666 |    |    |    | .548        |
| Q1(27)       | -909 |    |    |    | .548        |
| Q1(4)        | -706 |    |    |    | .807        |
| Q1(5)        | -807 |    |    |    | .807        |
| Q1(6)        | -420 |    |    |    | .807        |
| Q1(18)       | -357 |    |    |    | .807        |
| Q1(19)       | -560 |    |    |    | .807        |
| Q1(1)        | .480 |    |    |    |             |
| Q1(2)        | .430 |    |    |    |             |
| Q1(3)        | .365 |    |    |    |             |
| Q1(16)       | .329 |    |    |    |             |

Kaiser-Meyer-Olkin Measure of Sampling Adequacy of standard formation suitability 0.886

Bartlett’s sphere formation test
Approximate chi square 3,969.707
Degree of freedom 435
Probability of significance .000

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between variables was deemed significant, and the data were considered appropriate for carrying out factor analysis.

Among the four factors extracted by exploratory factor analysis, the first was classified as emotional awakening and the third as empathetic concern. The second and fourth factors were matched with the items developed by revising Davis’s empathy scale to take a view appropriate for a scientific situation, and both factors were considered as one (taking perspective). The Cronbach’s α was 0.744 for the first factor (empathic arousal), 0.707 for the second and fourth (taking perspective), and 0.807 for the third (empathic attention).

### 3.5.2. Results of the exploratory factor analysis of the scientific empathy with problem situations

SPSS was used to perform two rounds of exploratory factor analysis, and the factor was categorized for 19 items except for 1 with low reliability (no.2). The results of the exploratory factor analysis of the 18 items are as follows (Table 11).

The KMO value for the standard formation suitability was 0.922, which was higher than the standard value of 0.50; thus, the data were suitable for factor analysis. Additionally, the probability of Bartlett’s externality test was less than 0.01; therefore, the correlation between the variables was significant, and the data were appropriate for performing the analysis of the causes. The Cronbach’s α values for each factor were 0.796 for the first, 0.824 for the second, and 0.791 for the third. Of the three factors extracted by exploratory factor analysis, the first (Cronbach’s α = 0.796) was almost

| Question no. | Factor 1 | Factor 2 | Factor 3 | Cronbach’s α |
|--------------|----------|----------|----------|---------------|
| Q2(1)        | .207     |          |          | 0.796         |
| Q2(7)        | .575     |          |          |               |
| Q2(8)        | .658     |          |          |               |
| Q2(12)       | .389     |          |          |               |
| Q2(13)       | .283     |          |          |               |
| Q2(15)       | .687     |          |          |               |
| Q2(16)       | .579     |          |          |               |
| Q2(17)       | .706     |          |          |               |
| Q2(4)        | -.556    |          |          | 0.824         |
| Q2(5)        | -.738    |          |          |               |
| Q2(6)        | -.352    |          |          |               |
| Q2(9)        | -.499    |          |          |               |
| Q2(3)        | -.683    |          |          | 0.791         |
| Q2(10)       | -.276    |          |          |               |
| Q2(11)       | -.439    |          |          |               |
| Q2(14)       | -.764    |          |          |               |
| Q2(18)       | -.408    |          |          |               |
| Q2(19)       | -.377    |          |          |               |

Kaiser-Meyer-Olkin Measure of Sampling Adequacy of standard formation suitability 0.922

Bartlett’s sphere formation test

| Approximate chi square          | 2,427,938 |
|--------------------------------|----------|
| Degree of freedom               | 171      |
| Probability of significance     | .000     |
identical to the item developed from the viewpoint of scientific empathy with a problem situation, and the second (Cronbach's $\alpha = 0.824$) and third (Cronbach's $\alpha = 0.791$) were classified as scientific imagination. The second factor was related to imagination, and the third was a measure of curiosity and commitment. These were all included in scientific imagination. In addition, when the reliability was measured by combining the second and third factors, it was higher than the respective confidence (Cronbach's $\alpha = 0.867$). Through consultation with four experts, the second and third factors were grouped as one factor and classified as scientific imagination.

3.6. Empathy scale according to scientific situation

Through the development of two items and the results of the exploratory factor analysis, scientific empathy for others was classified into three factors and scientific empathy with problem situations into two factors as follows.

3.6.1. Scientific empathy for others

3.6.1.1. Perspective-taking. Perspective-taking is the tendency to voluntarily take the psychological viewpoint or attitude of another person. The item scale developed based on Davis's perspective-taking (Davis, 1980) is expressed as a PT, and the results of the exploratory factor analysis from the development of the second item were summarized as seven items.

3.6.1.2. Empathic concern. Empathic concern is the tendency to have an emotional response more consistent with the situation of others and to be interested in them. The item scale developed based on Davis's empathic concern (Davis, 1980) is expressed as an EC. According to the exploratory factor analysis, among the seven items developed based on Davis (1980), five items were combined into one factor, except for No.28, which is an effort factor for collaboration, and No.29, which is less reliable. So the final factor's content became five items.

3.6.1.3. Empathic arousal. Empathic arousal is the tendency for emotions such as other people's feelings, will, and thoughts to be transferred to oneself (share emotions and understand the position of others). An item scale that was developed based on Davis's personal pain scale (Davis, 1980) was expressed as a PD. Developed items were added by referring to the items of the emotional empathy scale of Kim (1997), Park (1997), and Moon (1999).

According to the exploratory factor analysis, two less reliable items (Nos.9 and 20) based on Davis's IRI (1980) were eliminated, and five items developed by Kim (1997), Park (1997), and Moon (1999) were combined into one factor.

3.6.2. Scientific empathy with problem situations

3.6.2.1. Perspective-taking. Perspective-taking corresponds to scientific empathy with problem situations and constitutes a tendency to take the position or viewpoint of a subject or problematic situation in a study. The item scale that was developed based on Davis's perspective-taking (Davis, 1980) was expressed as a PT. According to the exploratory factor analysis, among the seven items developed based on Davis's IRI (1980), six were combined into one factor, except for No.2, which was less reliable. Nos.15 and 16 were also included in the factor; thus, the final factor was composed of eight items.

3.6.2.2. Scientific imagination. Scientific imagination is not only the tendency to imagine a feeling in a fictional situation but also to exercise curiosity about a surrounding phenomenon and to immerse oneself in a problem based on scientific knowledge rooted in reality as well as to think in a novel way. This is related to a study by Lee and Chin (2014), which defines scientific imagination as being emotionally sensible about scientific knowledge and understanding as a new way of productive understanding based on scientific knowledge. Five scale items used in the factor analysis related to scientific empathy with problem situations in the second study were developed by referring to “curiosity,” “diffuse thinking,” “interest in various things,” and “openness.” The results of the exploratory factor analysis showed that three of the items were grouped into three factors in the final factor analysis. Four of the seven items based on Davis's IRI (1980)
| Category            | Factor           | Item number | Contents                                                                                                                                 |
|---------------------|------------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Others              | Cognitive        |             |                                                                                                                                          |
|                     | Perspective-taking | 3          | I respect the diverse ideas that friends have when conducting scientific experiments.                                                        |
|                     |                   | 4          | I try to listen to the thoughts of many people before making a decision about something during a science experiment.                          |
| Affective           | Empathic concern | 8          | When I see a friend who is being bullied during a science experiment, I like to protect him.                                              |
|                     |                   | 9          | I want to help my friend who is ignored and treated unfairly for no reason in a group of activities because I care.                         |
|                     | Empathic arousal  | 14         | I hate to do science experiment when my friends get bored and don't feel motivated during scientific experiments.                           |
|                     |                   | 17         | I feel nervous when the class is in a tense atmosphere during scientific experiments.                                                      |
| Problem Situation   | Cognitive        |             |                                                                                                                                          |
|                     | Perspective-taking | 2          | I try to think in many ways when I have scientific problems to solve.                                                                       |
|                     |                   | 6          | I try to put myself in the shoes of the study object to gain a better understanding of the scientific problem situation.                     |
|                     | Scientific imagination | 11     | I feel like I have become part of the problem when I have a problem to solve.                                                             |
|                     |                   | 14         | I keep thinking of problems in my head and consider various solutions when I am given interesting problems.                                 |
were the second factor, and the remaining three were grouped as the third factor. Factor 2 was composed of questions about imagination and those of Factor 3 were about commitment and diverse interests. Finally, 10 items were developed for scientific imagination by grouping the second and third factors into 1 measuring scientific imagination.

Finally, the final developed empathy scale in scientific situations was analyzed in two ways: in terms of empathy for others and in terms of empathy with a problem situation. The sub-factors were 5 items and 5–10 items for each sub-scale. Some of the final items of the scientific empathy scale are presented in Table 12 for each subscale.

4. Conclusion and proposal

Society must effectively stimulate collaboration with a variety of people with different capacities through flexible and creative thinking, and in the process, a spirit of openness, sharing, and participation is urgently required. Therefore, talented people who can demonstrate the ability to creatively resolve problems to create knowledge are important to society. The ability to solve problems based on mutual respect and trust among the members of society is also crucial.

Therefore, this study discussed the necessity of scientific empathy to stimulate the problem-solving ability creatively and collaboratively. To form a link between empathy and science education, we classified scientific empathy into empathy with problem situations and empathy with others based on an analysis of scientific cases and a review of the literature on the new definition of empathy in science education. The questionnaires were developed through the methods of generic model overlay and major event, and factor analysis was conducted on scientific empathy variables. Finally, a scientific empathy scale framework was constructed with the framework of Davis’s empathy scales based on the above studies. This led to the development of questionnaires for the scientific empathy scale that were given to students. And the results were summarized by exploring factors analysis. The conclusions of this study are as follows.

First, to discuss the role of empathy in science subjects, a reinterpretation of empathy elements (cognitive and emotional empathy) was used for the existing empathy, and empathy in science education should be treated as important not only for scientific empathy for others but also for empathy with problem situations. Imagination, a sub-element of cognitive empathy, should be considered in correlation with scientific imagination based on fact as well as on the content of others and fictitious situations.

Second, in the process of recognizing the problem, collaborative problem-solving processes are related to the ability to empathize by sharing importance, exploring problematic situations, and collaborating with colleagues. Thus, to improve empathy skills in a science class, the proper empathy strategies are needed at each stage of the process. Engaging in problematic situations and demonstrating scientific imagination can help identify problems and reach solutions. This requires an effective empathy strategy that can enhance immersion and scientific imagination to improve the ability to empathize.

Third, the scientific empathy scale usable in a scientific situation is expected to complement the limit of introducing an empathic ability scale in such a class. In general, Davis’s empathy scale (Davis, 1980) consists of cognitive and emotional factors, and Carkhuff’s empathic comprehension scale (Carkhuff, 1969), which is widely used as an expressive empathy scale, comprises essay-type items that could interfere with the scorer’s subjectivity. The items of the empathy scale usable in a science class were characterized by introducing science class situations to the items of the general empathy scale.

Because the emotional factor scale generally consists of questions on personality traits, items of this scale are not easily changed over the short term and should be supplemented. The questionnaire of this scale can help understand the improvement of empathic ability, and this study has effectively introduced empathy to science education. Such results are also expected to be used as basic data for program and strategy development to boost the ability to empathize.
Because this study is based on empathy, one limitation is that the hierarchy of empathy is unclear in the context of science education. However, this study is rare in that it tried to develop an evaluation scale by applying this as an educational factor compared to what is mentioned in society as a whole. To better study empathy in science, the general empathy scale must be reconstructed for use in the relations and hierarchy among the sub-elements within the context of science education. Such a scale would make the development of human skills through science education measurable as well as confirm the value of student ability to interact with and within problematic science situations. Such things are difficult to identify within a conventional science class. It would also confirm students’ collaborative problem-solving ability within more formal assessment situations and be of some use for student self-evaluation. Finally, the sub-elements of such a scale could be used to design lessons specifically intended to enhance students’ scientific empathetic ability.

However, revision and complementation of the testing of empathic ability are needed through a deeper analysis process on the relationship between scientific literacy and empathy. In addition, to generalize the concepts and attributes of empathy in science education and to raise the possibility of applying them to the field, follow-up studies are crucial to review the factors extracted in this study.

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