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# Science Teachers' Perceptions of and Approaches towards Students' Misconceptions on Photosynthesis: A Comparison Study between US and Korea

Kyungwoon Seo
Minnesota State University, Mankato, USA
Soonhye Park
North Carolina State University, USA
Aeran Choi
Ewha Womans University, SOUTH KOREA

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**ABSTRACT**
A critical component of teacher effectiveness is how teachers notice students' misconceptions and adjust the instructional approach accordingly. Taking a stance that the teachers' instructional quality is crucial to students' learning, a qualitative international comparison study was performed to examine science teachers' perceptions of and their approaches toward students' misconception on photosynthesis between the United States (US) and South Korea. A web-based on-line survey consisting of open-ended questions was administered to secondary science teachers and 85 and 81 teacher responses were collected from the US and Korea, respectively. Constructed responses were analyzed using the constant comparative method and enumerative approach through which regularities and patterns in the responses emerged. Four categories emerged concerning teacher perceptions of misconceptions: Concept, Knowledge Construction, Curriculum, and Pedagogical. Most teachers employed Concept or Knowledge Construction perspective to identify and reason out student misconceptions in both countries. In respect to instructional strategies, two dominant patterns emerged: content-focused and student-focused strategies. Teachers from both countries demonstrated the most frequent use of content-centered approaches, although the patterns of the usage in relation to their perceptions towards misconceptions were different to some degree. Possible attributing factors for the observed patterns and some limitations of the study are further discussed.
**Keywords:** Constructivism, Instructional Strategies, Misconception, Pedagogical Content Knowledge, Photosynthesis


**Correspondence:** Aeran Choi, *Ewha Womans University, Ewhayeodaegil 52, Daehyun dong, Seodaemun gu, 03760 Seoul, South Korea*
achoi@ewha.ac.kr

**State of the literature**

- Teachers in different societal contexts share a common view of constructivist teaching.
- The extent to which the teaching practices reflect the role of students' misconceptions is one of the indicators for constructivist teaching.
- Multi-faceted complexities exist when teachers adapt their instructional tasks to provide learner-centered constructivist teaching practices.

**Contribution of this paper to the literature**

- This study provides an overview of a comparison between countries that differ in their unique science education system, teacher education system, and teacher characteristics.
- This qualitative study provides rich descriptions of practicing teachers' accounts, which adds to a body of comparative research that mostly employ quantitative research method.
- The findings of the study demonstrate that teachers in different societal contexts show overall similarities in their perceptions towards students' misconceptions, while some discrepancies exist in designing appropriate instructional approaches for teaching photosynthesis.

## INTRODUCTION

Constructivist perspective has long served a critical role in the research field, providing ways to examine the effective learning of students in relation to effective teaching. Based on the premise that "effective learning occurs when individuals construct their own understanding" (McInerney, 2013, p.4), vigorous conversation among practictioners at different educational levels and across countries has led to the shared view that "a more constructivist or student-centered pedagogy may be more effective for deeper learning than the traditional transmissive pedagogy" (Fensham, 2011, p.706). Empirical evidence also supports that students in constructivist classrooms outperform their counterparts in teacher-centered classrooms (e.g., Banet & Ayuso, 2003; Becker & Maunsaiyat, 2004; Huffman, Goldberg, Michlin, 2003). In this regard, to facilitate student learning, teachers first need to understand and internalize the key idea of constructivism that students construct scientific understanding linking new ideas to their existing conceptual framework (Fosnot, 1996). Based on that, they also need to implement pedagogical approaches compatible with constructivism that emphasize students' prior knowledge, student ownership for knowledge construction, and the importance of social interactions (Hardy, Moller & Stern, 2006). Teachers' awareness of students' misconceptions has long been coined with student learning (Sadler, Sonnert, Coyle, Cook-Smith & Miller, 2013) and thus, this study is concerned with how teachers perceive students' misconceptions and how these misconceptions are pedagogically approached using diverse instructional strategies, two key areas critical to providing the constructivist learning environment.

Windschitl (2002) argues that creating constructivist learning environment is neither a simple nor easy task for teachers because teachers often face conceptual, pedagogical, cultural and political challenges when they attempt to frame constructivism in real practice. While conceptual and pedagogical challenges are rooted in teachers' personal and intellectual comprehensive knowledge of constructivism related to designing/implementing of learning experiences that constructivism demands, cultural and political dilemmas are associated with structural and public concerns of the learning community. In terms of cultural dilemma, the classroom culture associated with how teacher-student relationships are established has been shown to impact the success of constructivist teaching (e.g., Hardy, Jonen, Moller, & Stern, 2006; Selley, 2013) Also, political dilemmas have been reported as teachers confront controversy over constructivist teaching when communicating with other educational stakeholders -such as parents or school administrators- who are resilient to the reformed practices (e.g., Lee & Fraser, 2000; Oakes et al. 2000). In this vein, more research is warranted to explore how different cultural or political backgrounds impact teachers' enactment of constructivist teaching, which can provide insights into cultural myths and political contexts that could hinder the enactment of constructivist teaching (Tobin & McRobbie, 1996).

Moverover, as the world becomes increasingly interdependent and competitive, growing emphasis on globalization has been influencing policies and practices in science education internationally (DeBoer, 2011). This trend is strongly reflected in the area of science assessment, for example, as large-scale international standardized testing programs (e.g. Programme for International Student Assessment (PISA), Trends in Mathematics and Science Study (TIMSS)) provide participating countries an opportunity to compare their students to a common standard and to students in other countries. These international comparison assessments often trigger a reform movement in science education in the countries to improve their students' science achievement. For example, in the US, an international science benchmarking report entitled " Taking the Lead in Science Education: Forging Next-Generation Science Standards (Achieve Inc., 2010)" was released to inform the development of the conceptual framework and new US science standards by examining the standards of 10 countries which performances on international assessments are strong and/or which economic, political, or cultural importance to the US is significant including Canada, Finland, and South Korea. Also, PISA and TIMSS data are frequently used in international comparative studies to explore and investigate important factors impacting students' performance and to provide implications for improving science education system (e.g., Shin, Lee, & Kim, 2009; Kim, Ham, & Paine, 2011).

However, any reform movement in science education ultimately calls for changes in teaching practices given that teachers are the critical mediator between reform and student achievement. A growing body of research have supported a critical role of teachers in student learning gains (Hill, Rowan, & Ball, 2005; Schmidt et al., 2007; Wayne & Youngs, 2003). In this vein, this study aims to compare teachers' perceptions of and approaches to student misconceptions that are some of the important aspects of constructivism-oriented teaching in two countries: US and South Korea. The two countries are substantially different in education system, culture, and sociopolitical contexts. South Korea was reported to have overall high teacher quality and considerable equity to access highly qualified teachers, as compared to the US (Akiba, LeTendre, & Scribner, 2007). Kang and Hong (2008) argue that social factors such as cultural respect for the teachers, social cognition, and occupational conditions make the teaching profession highly respected. With respect to student science achievement, according to the 2009 PISA results in Sciences for all 34 OECD members and 37 partner countries, South Korea was ranked the 3rd while US was ranked 17th. Despite those differences, both US and Korea share a common emphasis on the constructivist nature of science learning in the curriculum reform efforts and national science standards (documented in A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas by National Research Council, 2012 and in the revised 7th Korea national curriculum standards by Ministry of Education and Human Resources Development, 2007 for the US and South Korea, respectively).

In an effort to further investigate the multi-faceted complexities -teachers in different societal contexts simultaneously anticipated to implement constructivist teaching-, the purpose of the study is to take a closer look at how teachers in the two counties notice students' misconceptions and design appropriate instructional approaches accordingly in a classroom setting. In particular, the study explored and compared teacher perceptions of students' misconception on photosynthesis and the characteristics of teachers' approaches to address the misconceptions in the US and South Korea. The research questions that guided this study are: (1) how do teachers in both countries perceive student's misconceptions? (2) How do teachers in both countries approach towards student's misconceptions in their instruction? And (3) how are the teachers' perceptions related to their instructional strategies?

## THEORETICAL BACKGROUND

### Constructivism

The theoretical framework of the study stems from the learning theories that are constructivist in nature. Although there is "no single constructivist theory" (O'Donnell, 2012), the study is firmly grounded in the notion that the learner actively constructs knowledge and that the learner' prior knowledge and/or experiences inform and influence the knowledge construction process. Constructivism has been a profound driving force impacting the K-12 science education system as basis for reform-oriented teaching (Matthews, 2002) and curriculum development and implementation (Coll & Taylor, 2012). Although some researchers have raised concerns that the descriptive literature on constructivism is often fragmented and impractical (Bavisker et al., 2009; Crowther, 1999; Jenkins, 2000) and that "the cognitive premises of constructivism can dictate only guidelines for good teaching (Noddings, 1990, p,15)," constructivism is generally conceived as a theory of learning from a phenomenological stance, to describe "the range and structure of experiences that make up constructivist teaching" (Windschtl, 2002, p.132).

Constructivism has two dominant strands that have descended from different philosophical view, radical/psychological constructivism and social constructivism. While radical constructivism puts more emphasis on the cognitive aspect of individuals' construction of knowledge (Mason, 2007), social constructivism is concerned more with "the contributions of social interactions to the construction of self" (Atwater, 1996). As the two different viewpoints reside on the relative role of the learner and context, both perspectives are valuable in understanding constructivist teaching in various contexts and hence, are reflected in the study. Influence of radical constructivism on science teaching, specifically focused on students' misconceptions, is first discussed, followed by the perspective of teachers as learners from a social constructivism lens.

## Students' Misconceptions and Pedagogical Strategies

The degree to which the role of students' misconceptions is reflected in the teaching practices is often considered as an indicator of constructivist teaching (e.g., Uzuntiryaki, Kirbulut & Bektas, 2010). In the earlier review of lierature on students' misconceptions in science (Smith, diSessa & Rochelle, 1994), the authors identified seven general assertions about learning that were frequently expressed: 1) students have misconception, 2) misconceptions originate in prior learning, 3) misconceptions can be stable and widespread among students/misconceptions can be strongly held and resistant to change, 4) misconceptions interfere with learning, 5) misconceptions must be replaced, and 6) instruction should confront misconceptions and research should identify misconceptions. The authors further examined the inconsistencies between some of the views with the basic premise of constructivism, and suggested an alternative framework to conceive knowledge as a "complex system of numerous elements (p.149)". Hence, rather than focusing on replacing misconception, it was advocated that the goal of instruction should be to provide the experiential basis for the complex system of knowledge.

In a study by Baviskar, Hartle and Whitney (2009), the authors described four essential criteria to characterize constructivist teaching: eliciting prior knowledge, creating cognitive dissonance, application of new knowledge with feedback, and reflection on learning. In particular, eliciting and organizing the information of student's cognitive is key to assessing misconceptions, which becomes the target for implementing the instruction accordingly. Adaptations of instructional tasks to address students' prior knowledge and misconception are often perceived as learner-centered instructional practices (Bonk & Cunningham, 1998). Various reports support that carefully scaffolded classroom-based constructivist instruction guidance is necessary to avoid students developing misconceptions (Moreno, 2004; Tuovinen & Sweller, 1999).

## Teacher as Learner

As Spalding, Klecka, Lin, Wang and Odell (2011) stated "learning to teach is a continuum that only begins with a teacher education program and extends throughout one's career" (p.5). Becoming of a teacher begins with going through the teacher education system where the teacher candidate is exposed to different areas of study to develop understanding in various aspects, such as pedagogical or content knowledge of the subject discipline. Learning process continues throughout their teaching career. In addition to such daily practice, some teachers may even go further to participate in professional development programs. In this regard, the current study is built on the theoretical framework that such learning processes cannot be considered independently of the context surrounding the learning individual. This perspective, namely, social constructivism or sociocultural perspective, is well-described by Rumelhart and Norman (1981) that,

> Our ability to reason and use our knowledge appears to depend strongly on the context in which the knowledge is required. Most of the reasoning we do apparently does not involve the application of general-purpose reasoning skills. Rather it seems that most of our reasoning ability is tied to particular bodies of knowledge. (p. 338)

Adopting a social constructivist lens, teachers are involved in various interactions throughout their career; from their classrooms, to a larger school district, and even to a teaching community as a whole. Because all of the settings involved are intricately related within a cultural context of a country for a teacher, this study brings a valuable perspective to view the teachers in different countries with a sociocultural lens.

## SCIENCE EDUCATION IN THE US AND KOREA

### Science Education System

Growing interest in the integrative perspective of science discipline with other disciplinary areas influenced the research field internationally, directly affecting both countries. In the case of the US, this integrative aspect is specifically referred to as STEM education, abbreviated from "Science, Technology, Engineering, and Mathematics" education. According to the Congressional Research Service report in 2008, increased concern for incompetence of US students in terms of National Assessment of Educational Progress (NAEP) emphasizes the need for improving students' knowledge of math and science. In order to remedy the inconsistency of the "nation's role as a world leader in scientific innovation" and the poor students achievement in math and science, the report calls for federal policy actions with a number of legislative options in order to resolve the problem.

Focus on the interdisciplinary nature of science is also reflected in South Korea in the 7th Korea National curriculum standards by Ministry of Education and Human Resources Development. As reviewed in Han's study (1995), "the education law specifies the school curriculum for each level of formal education" in Korea, resulting in all the schools using the same national science curriculum. While the uniqueness of its highly standardized and centralized education system would influence teacher practice in classrooms, the 7th Korea national curriculum standards emphasizes the interdisciplinary nature of science and incorporate all four sub-disciplines of science (i.e. physics, chemistry, biology, and earth science) into one single curriculum.

## Science Teacher Education Context

In the most states of the US, initial teaching certificate is awarded after completing the course requirements of the teacher education program and passing the state teacher-licensing assessment. However, wide variations exist on the standards and policies concerning teacher education programs and teaching certification process across the states. Furthermore, the hiring of the teaching professionals is done both at the school and school district level, which reflects decentralized education system of the US (Wang et al., 2003). In contrast, Korea has centralized teacher education system and the established curricular requirements for secondary teaching certifications are almost uniform across various institutions. Furthermore, more rigorous screening process is applied in throughout the teacher education system (Hong & Kang, 2010).

With regard to the science teacher education curriculum in the Midwest state which is the context of the study, state-mandated prerequisite coursework for secondary science teachers involves the completion of either 24 semester hours in specific content area (biology, chemistry, earth science, or physics), along with 10-12 semester hours of subject-related pedagogy. With varying degree by institutions, field experience is commonly required with practicum, followed by extensive student teaching experience that typically expands over three semesters. With respect to the Certification process, passing a nationally recognized testing service (Praxis II Tests, developed by Educational Testing Service (ETS)) in two areas is mandated: a general pedagogy area (Principles of Learning and Teaching (PLT)) and a subject-specific area (biology, chemistry, earth science, or physics) for content proficiency. The minimum requirement to pass the tests in the state of the study is to perform above twenty-fifth percentile nationally.

On the other hand, pre-service science teachers in Korea are required to complete a minimum of 33 semester hours in their subject area, 9 semester hours of subject-related pedagogy, and 14 semester hours of general pedagogy. Some schools also mandate additional content-related coursework required to teach general science. In addition, student teaching is required for 4 weeks towards the end of the teacher education program, and some institutions also require teaching experience in non-school environment. Although no additional assessment is required for licensure, pre-service teachers need to pass a high-stake employment test (National Teacher Employment Test; NTET) to be hired to teach at a public school. Passing NTET, a test which mainly assesses the content and content-related pedagogy, is extremely competitive as it is dependent upon the very limited number of projected openings each year.

## Science Teacher Characteristics

In Hong and Kang's study (2010), the authors compared the US and South Korea secondary science teachers' conceptions of creativity and teaching for creativity using open-ended and Likert-type questionnaires. They found that "the South Korean teachers tended to consider ethics as a more important criterion for judging creativity than the US teachers and emphasized providing thinking opportunity for fostering creativity, while the US teachers emphasized environmental or emotional support" (p.821). They also argued that constraints such as pressure to cover the content materials for high-stakes exams, class size, and challenges in the creativity assessment may have been influential factors to the differences.

Campbell and his colleagues (2010) conducted a comparative study of US and Korea 9-12th grade science classroom instructions from the perspectives of current reform in science education in both countries. Sixty-six classroom observations were analyzed by using the Reformed Teaching Observation Protocol (RTOP) (Sawada et al., 2002) to examine the extent to which principles of constructivism framing both countries' science standards were reflected in real classrooms. Quantitative analysis revealed more similarities than the differences between Korea and US classrooms that indicate that both countries need improvement in aligning student experiences in science classrooms with those visions outlined by reform efforts framed by principles of constructivism.

A limited number of comparative studies suggests that more research is needed to understand better the similarities and/or differences between the teachers in the US and Korea. Also, most of the studies conducted employ quantitative research method that does not provide richer descriptions. Thus, the findings of this qualitative study would be important to fill in the gap in the field on a cross-national comparative study on teachers in Korea and the US.

## METHODS

### Research Design

For this study, a generic qualitative research design was employed (Merriam, 1988). According to Merriam (1998), a generic qualitative study seeks to "discover and understand a phenomenon, a process, or the perspectives of worldviews of the people involved" (p.11). Thus, in line with the overall aim of the study to provide a detailed description from the teachers' perspective, generic qualitative research design was considered appropriate for the study. Furthermore, a topic with comparable curricular emphasis in both countries was necessary to provide a valid comparison. The specific topic on photosynthesis, a well-researched area which constitutes a large portion of biology curriculum in both countries, was chosen as the study context was grounded in the earlier work (Park & Suh, 2015) focused on photosynthesis.

### Data Collection

In order to explore how teachers in both countries approach and challenge students' misconceptions, teachers' constructed responses from open-ended survey items were analyzed. The survey was originally developed and used in a study (Park & Suh, 2015) that aimed to assess two key components of pedagogical content knowledge (PCK), i.e., knowledge of student understanding and knowledge of instructional strategies and representations, for teaching photosynthesis at grades 9 and 10. The survey consists of 30 dichotomous items and open-ended questions based on six classroom scenarios (An example of a scenario is provided in the Appendix A). For each classroom scenario, except for the sixth scenario, there are three sets of questions. The first set of questions includes three or four dichotomous items that ask respondents to identify student misconceptions in the given scenario. The second set question is an open-ended question that requires them to reason out why students often have the misconceptions that they identified in the previous dichotomous questions using the following prompt: In your experience, among the concepts listed in the above questions, which concept have you noticed most students have difficulty to understand? Why do you think that concept is difficult for students to learn?" The final set question is also an open-ended question that asks them to describe teaching strategies they used or would like to use to challenge the misconceptions, and to explain why such strategies worked or would work. The following prompt is used for the question: "What instructional strategies do you usually use (or would you like to use) to help students better understand the concept that you selected in the previous question?"

The survey was administered online to secondary science teachers in the US and South Korea and 85 and 81 complete surveys were collected, respectively. **Table 1** below summarizes the survey administration procedure in each country. Since the original survey was written in English, it was translated into Korean through the back translation method (Brislin, 1986), which involved three individuals who are bilingual in Korean and English. Specifically, the survey was first translated into Korean by one who was involved in the survey development and bilingual in Korean and English. This translation was then translated back into English by another individual who is bilingual in Korean and English but did not know the original English version of the survey. Following the back translation, another bilingual speaker assessed the accuracy and adequacy of the translation by comparing the back-translated version with the original English version. No modifications were made to the original survey in order to ensure consistent content.

**Table 1.** Survey Administration in the US and Korea

| | **US** | **South Korea** |
|---|---|---|
| **Survey Type** | On-line survey (Qualtrics) | |
| **Method of Delivery** | Email invitation including the survey link | |
| **Compensation** | $5.00 Amazon e-gift certificate | $10.00 Starbucks e-gift certificate |
| **Number of surveys distributed** | 2024 secondary science teachers in a Midwestern US state | 500 secondary science teachers in two large Metropolitan cities |
| **Number of completed surveys** | 85 | 81 |

At the beginning of the survey, a separate section was devoted to collecting demographic information of the participants. The majority of the science teachers in both countries who completed the survey were teaching biology at the high-school level, which may result from the issue that the topic of the survey was photosynthesis. Distributions of the gender, age, and teaching experience differed to some extent between the two countries, with relatively more number of experienced teachers in terms of their years of teaching experience participated from US. While a more detailed demographic distribution of teachers is provided in Appendix B, it should be noted that although the two groups comprise the context of the study, participants were non-random samples, given the non-experimental design of the study, and were not to be conceived as the representative groups from both countries. The study was approved by the IRB at a US institution, successfully meeting the requirements of the protection of human subjects, which also included a mandatory review process by a local contact expert in Korea.

## Data Analysis

For the purpose of this current study, only teacher responses to the open-ended questions for the five classroom scenarios were used. The questions about the 6th classroom scenario were excluded because they are not directly related to the focus of this study. Teachers' constructed responses to 10 open-ended questions (i.e., 2 questions for each of the five scenarios) were first analyzed using the constant comparative method (Strauss & Corbin, 1994) to identify patterns in the similarities and differences in teacher responses from the two countries. In this analysis approach, the first author of this paper open coded teacher's responses without a pre-established set of codes. The open coding process was repeated multiple times until a list of codes was finalized. During this iterative process, several responses were randomly selected at regular interval and coded independently by the second author to calculate inter-rater reliability. Any disagreements were discussed until we reach agreement through discussion involving the third author. Initial inter-rater reliability was around 80% and it reached over 90 % on average toward the end of the open coding phase. Korea teachers' responses were analyzed in Korean without translation into English to avoid any distortion of the meaning and nuance the translation could cause. This approach was possible because all involved in the analysis process are bilingual in Korean and English. Due to the nature of the survey responses, responses that failed to directly address the research question, such as "n/a", or, "I don't know", were removed.

Next, the codes identified were grouped into categories through comparison and contrast method. The emerging categories were then further combined by similarities, renamed, or modified through investigator triangulation (Patton, 2002). As a result, four major categories emerged to account for teachers' perceptions of student misconceptions, i.e., and research question 1: Content (CT) Perspective, Knowledge Construction (KC) Perspective, Curriculum (CC) Perspective, and Pedagogical/Instructional (PI) Perspective.

Concept (CT) perspective refers to the view that were most concerned with the specific nature of the content as a whole, which could further be classified into three different sub-groups: CT-A (Abstract nature), CT-D (Difficulty to conceptualize), and CT-T (Terminology issue). Subgroup CT-A concerns teachers' focus on the abstract nature of the concept as shown in the response: It is probably hard to understand for some because the idea is so abstract and you can't see it happening. While CT-D highlights the inherent difficulty of the topic for conceptualization (CT-D), CT-T is related to terminology issues associated with the concept.

In contrast to the emphasis of the CT category on certain nature of the concept, Knowledge Construction (KC) perspective denotes the responses focusing more on making connections during the knowledge construction process that comprises the concept. This category has three subcategories: KC-L (Lack or absence of a related/necessary content), KC-C (Confusions that occur when connecting the ideas mostly due to weak understanding of underlying mechanism), and KC-M (inherent misconceptions or inaccurate/inappropriate way of thinking students hold when they are learning the content).

Curriculum (CC) perspective refers to accounts that direct the cause of students' misconception to the sequence of the curriculum concerned with the topic. Teacher responses in this category often eluded the hierarchical structure of disciplinary knowledge between biology and chemistry, as the nature of the topic in the survey, photosynthesis, was a biochemical process. Also, responses in this category showed a very close linkage to KC-L, described above, such that the issue in the curriculum leads to the lack of relevant information/material.

Lastly, responses concerned with the effect of instruction on students' misconception were categorized as Pedagogical/Instructional (PI) perspective. Similar to the linkage between CC and KC-L, PI perspective was shown to be closely related to students' knowledge construction process, especially as an influence in students' struggle in making connections between ideas (KC-C) or as a means by which to develop an inherent misconception within students (KC-M). Nonetheless, parallel to the logic behind differentiating CC and KC-L as described above, students' difficulties in their knowledge construction process were considered as consequences of instruction, resulting in PI perspective as a separate category from KC perspective. **Figure 1** illustrates the four major categories and their connections (codebook for each of the categories with corresponding examples are provided in Appendix C).

With respect to teachers' instructional approaches toward misconceptions, i.e., research question 2, two dominant categories emerged: Content-focused and Student-focused. Content-focused refers to teachers' approach that emphasizes content components necessary to challenge the misconceptions without any specific notion of the involvement of students. This category includes Repeating/Emphasizing (RE), Concept-Explanation (CE) and Demonstrating (DR) strategies. RE refers to an instructional strategy that does not show any significant change from an earlier attempt (e.g., we go over the info again and again; Stress that plants are living things). CE approaches specifically aim to target certain concepts, modifying what the content is, which may involve inclusion of additional related information, detailed clarifying explanation on certain concepts or any modification of the specific sequence of the content during instruction. Lastly, DR indicates approaches that show the teacher's effort to demonstrate an idea or a concept in a different way, such as using diagrams, examples or analogy, with more emphasis is put on how the concept is presented and explained.

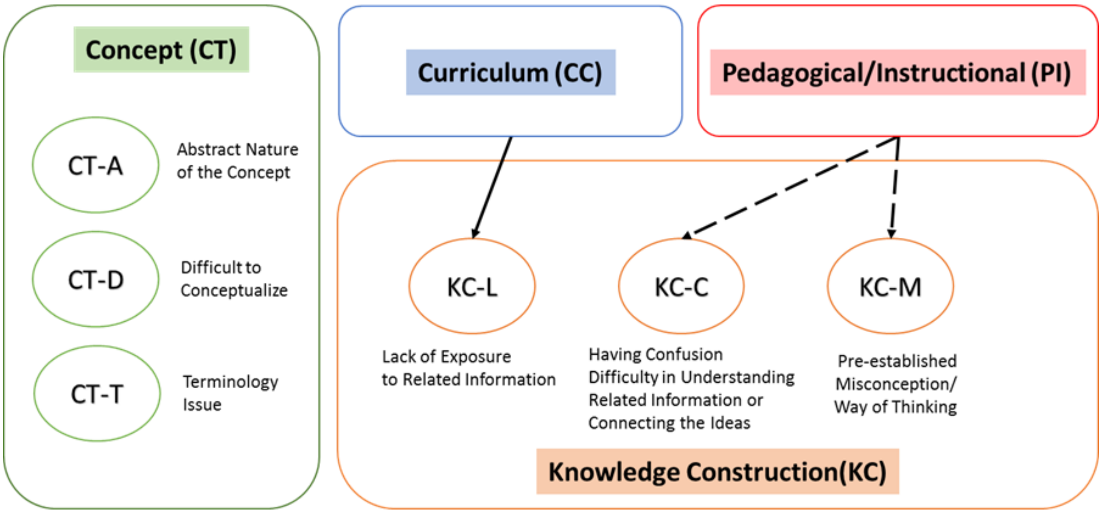


**Figure 1.** Schematic Representation of Teacher Perceptions towards Misconceptions

In contrast, Student-focused (SF) refers to instructional approaches that involve varying degrees of student participation. This category includes three approaches: Relating (RL), Activity (AT) and Responding (RP). In RL approaches, teachers try to relate the idea or concept to the student's prior knowledge or experience actively. AT refers to approaches that aim to involve students' direct participation that takes the form of hands-on activities or group discussion. Lastly, RP represents approaches where teachers constantly assess students' learning and/or further demonstrate their openness to the students' feedback or response to their instruction. The codebook with exemplary quotes from the teachers is provided in the Appendix D.

In addition to the constant comparative method, enumerative approach was used (LeCompte &Preissle, 1993) in which the frequency of each category and subcategory was counted in order to examine patterns in the distribution of the categories and sub-categories for teacher perceptions and instructional approaches between the two countries.

In order to answer research question 3, i.e., connection between teacher perceptions and instructional strategies, responses were first clustered according to their perception categories, and then were paired with its corresponding instructional strategies for individual teachers. Consequently, differential use of the instructional strategies within each of the perspective category could be determined. Responses that contained only one of each pairs (e.g., when a teacher provided his/her perspective on misconception, but did not respond to the corresponding instructional strategy, or, vice versa) were excluded during the analysis process.

## FINDINGS

### Teacher Perceptions towards Misconceptions

In terms of how teachers view students' misconceptions, two major content-focused views were most frequently discussed in the responses: Concept (CT) and Knowledge Construction (KC) perspectives. As shown in **Table 2**, CT perspective responses primarily focused on the nature of the content (e.g., complexity or abstractness of the topic) and terminology issues. More specifically, many teachers attributed student misconceptions to students' limited ability to concretize abstract concepts, as evident in the following experts from teacher response (excerpts from *U*S teachers and *K*orea *t*eachers are referred to as UT and KT, respectively):

"*this is due to the fact that they are not readily visible"* (KT 53)

*"because students have to be able to visualize what they can't see and put the process into a sequence*" (UT 49)

"*because it is not something that is […] tangible*" (KT 25)

"*students struggle because they have trouble saying something has energy stored in it unless they can sense it. (i.e. seeing motion; or sensing heat)"* (UT 75)

Terminology issues were also raised that hinder students' comprehension of the topic, which involved the concern for the vocabulary (at times, mislabeled) used on some of the concepts in photosynthesis (CT-T; e.g., UT 27: *calling them light and dark reactions is confusing*, or KT 27: *because of how it was named, students think photosystem 2 comes after photosystem 1*). One teacher provided a detailed elaboration of the problem, in that,

*'Students seem to think that the dark reactions only occur at night (in the dark). Not that they are named as such because they do not require light to occur. I believe that this occurs due to the unclear/confusing nomenclature of science. At no fault of science names and titles are chosen for things that when translated into the everyday speech students are familiar with the phases are confusing or even contradictory."* (UT 75)

Moreover, many teachers pointed out students' misconceptions arising from the *process* in which the students construct knowledge around the topic. Most of the responses in this category (Knowledge Construction perspective; KC) specifically stated where students struggle. KC-C perspective addressed various elements comprising the broad topic of photosynthesis, KC-L mentioned the missing links, and KC-M addressed inappropriately connected knowledge framework inherent in students' misconceptions. For examples, rather than vaguely describing the difficulty of the concept in general (CT-D; e.g., KT 1: *[because] it is a difficult topic to learn*), KC-C perspectives clearly described students' various difficulties in connecting related ideas:

> *"[because] they don't understand that the atoms of the reactants are rearranged to form compounds that have more chemical energy"* (UT 68)
>
> *"students do not understand the ultimate purpose of photosynthesis and respiration. That is, the purpose of photosynthesis is to make glucose as the energy source and respiration is to produce necessary energy for the organism"* (KT 81)

Also, because photosynthesis involves a series of biochemical steps, the lack of knowledge/experience in chemistry was frequently mentioned as the cause for the misconception (KC-L). In the following examples, teachers highlighted chemistry background as the basic source of understanding biochemical reactions in photosynthesis.

> *"Learning about the ETC in terms of oxidation and reduction without a chemistry background is like trying to learn a concept in an unfamiliar language"* (US 21)
>
> *"Without the knowledge of molecule structure from chemistry, it is difficult for students to conceptualize how NADPH is oxidized and matters are reduced"* (KT 60)

Overall, responses in KC-L were concerned with the lack of anchor points for newly learned information in the knowledge construction process (e.g., UT 18: […] *an overwhelming amount of entirely new information with little conceptual knowledge to tie it to*.)

Moreover, some teachers noticed the related misconception inherent in students' conceptual framework (e.g., KT 37: *students have a pre-misconception that photosynthesis occur during the day and respiration occurs only at night; [because] most think they only do photosynthesis and don't use oxygen;* KT 33: *they have the idea ALL things needed come through the roots*) which hinders subsequent knowledge construction process (e.g., UT74: *[t]his instill misconceptions that are hard to break in later grades*).

**Table 2.** Teacher Perceptions towards Misconceptions

| | Total | | US | | Korea | |
|---|---|---|---|---|---|---|
| **Perspective** | **Number** | **%** | **Number** | **%** | **Number** | **%** |
| **Concept (CT)** | 190 | 37% | 72 | 39% | 118 | 35% |
| Abstractness (CT-A) | 69 | 13% | 31 | 17% | 38 | 11% |
| Difficulty (CT-D) | 49 | 9% | 24 | 13% | 25 | 7% |
| Terminology (CT-T) | 72 | 14% | 17 | 9% | 55 | 16% |
| **Knowledge Construction (KC)** | 250 | 48% | 76 | 41% | 174 | 52% |
| Lack of Information (KC-L) | 51 | 10% | 22 | 12% | 29 | 9% |
| Issue with Making Connections (KC-C) | 115 | 22% | 27 | 15% | 88 | 26% |
| Pre-established Misconception (KC-M) | 84 | 16% | 27 | 15% | 57 | 17% |
| **Curriculum (CC)** | 22 | 4% | 18 | 10% | 4 | 1% |
| **Pedagogical/ Instructional (PI)** | 47 | 9% | 14 | 8% | 33 | 10% |
| **Others** | 10 | 2% | 5 | 3% | 5 | 1% |
| | **519** | **100%** | **185** | **100%** | **334** | **100%** |

Although CT and KC perspectives were most frequently observed in teachers' responses, other notable perspectives that were situated relatively distal to the specific content were also observed. These responses include teachers' accounts on the curriculum impact on students' misconception (CC; UT 82: *students have Biology before Chemistry and there isn't quite enough time in the curriculum to get through all the required Physics, Chemistry & Earth Science concepts in a 1-year required class to help them be successful in Biology*). Or, some teachers were addressing the awareness of students' developmental level in comprehending the topic (e.g., UT 52: *this is pretty high level for 14-16 year olds*), while others eluded to the role of instruction and/or pedagogy for students' misconception (PI) in terms of *what* is being taught, as in the first three examples, and *how* it is taught, as in the last two examples below.

> *"respiration is explained only with animal as examples" (*KT 36)

> *"I believe energy is a severely "mis-taught" concept, especially when students are taught there are "types" or "kinds" of energy. The emphasis needs to be on energy is transferred and converted"* (UT 14)

> *"many teachers give kids a limited conception of photosynthesis as only taking in CO2 and only giving off"* (UT 35)

> *"we teach dark reaction and light reaction separately" (*KT 71)

> "*respiration takes place in all cells - for plants, we emphasize the photosynthesis/ respiration connection, and in animals we emphasize the organ systems used to respire. We lose sight of the purpose of respiration"* (UT 81)

In general, similar patterns were observed in the US and Korea overall, as teachers in both countries emphasize on content-focused perceptions (CT and KC) towards students' misconception. However, between CT and KC, KC was observed to be the pre-dominant perspective held by the Korea teachers. **Table 2** clearly shows that the frequency of KC is higher than that of CT for Korea teachers, in contrast to US teachers' similar emphasis on both perspectives. Another difference between the two groups was a relatively low percentage of Korea teachers attributing students' misconception to the Curriculum (CC) as compared to that of US teachers. In fact, CC was hardly mentioned by Korea teachers. Lastly, similar percentages of responses were coded as Pedagogical and Instructional (PI) perspective for both groups.

To look at each of the perspectives more closely, a key difference between two groups' emphases on KC seemed to result from the high percentages of Korea teachers attributing students' misconceptions to the difficulties in understanding the necessary linkage required to understand the concept (KC-C). As such, within the category of Knowledge Construction perspective, difficulties in making connections either by confusion of the linkage (KC-C) or by already established misconceptions (KC-M), rather than the lack of relevant information (KC-L), were more emphasized for the Korea teachers,. The pattern of US teachers differed slightly in that they similarly emphasized each of the perspectives.

Within the category of Concept perspective, difficulty with the use of terminology was most frequent in Korea teachers' responses, followed by the abstractness of the concept, and the inherent difficulty in comprehending the concept. The pattern of the US teachers' responses differed in that the abstract nature of the concept is the most frequently observed factor, followed by the inherent difficulty of the concept, and then the terminology used.

### Teachers' Instructional Approach towards Misconceptions

Similar to the general pattern observed in teachers' perceptions towards misconceptions, strong emphasis on the content were also observed in their instructional strategies. Within such content-focused approaches, repeating/emphasizing strategies involved the least involvement of student participation and minimal change to the original instruction, which included responses such as,

"*Re-teach the type of energy involved*," [UT 39]

"*Emphasize strongly that respiration happens all the time*," [KT 31]

On the other hand, instructional approaches involving some changes to the original instruction occurred, either by providing more detailed explanation of the concept (CE; Concept Explanation) or by offering alternative ways to represent the ideas (DR; Demonstrating). CE approaches relied heavily on the content, in which teachers often elaborated on the need for providing specific details of the content materials (e.g., UT 78: *A teacher needs to spend time on a full explanation of the process not just give them enough information so that they can pass a test*.) Alternatively, diverse methods of demonstrating the ideas (DR) was also mentioned, such as using visual aids, changing the wordings, or providing different examples of certain phenomenon. As such, CE and DR approaches emphasized both *what* and *how* of the instruction.

While above-mentioned strategies were nonetheless strongly bound to the content with the least involvement of the students in the learning environment, teachers also discussed other approaches that engage students' participation. In particular, providing various activities for students (AT) was most frequently discussed. Although certain approaches in DR involved providing different opportunities, they did not necessarily require any students' actions (e.g., KT 57: *use various diagrams and animations*). However, AT approaches include the active participation of the students in a classroom environment, such as,

"*have students use physical objects that are labeled to put the process in the right order*" [UT 46]

"*students understand much more quickly when they are engaged in experiments, using mbl apparatus to measure the release of gas*" [KT 34]

"*have students interpret the graphs from Benson Experiment*" *[KT 36]* *"students do jigsaw activities to help them understand the conversion process then they explain their activities to the other groups."* [UT 16]

Although the majority of teachers' responses included a single instructional approach to act toward students' misconceptions, some teachers noted various combinations of different strategies (e.g., KT 20: *provide related content materials for students or let students do experiments to grow plants without soil)*. Sometimes, combinations were also observed within a particular approach, such as the following AT example of a teachers' response who used a classroom-activity in order to start the conversations in the classroom;

*"Have the class build and dissemble the molecules several times using our lego kits. Not everyone will do so at the same rate, and not all will get done at the same time, either. This is a good start to the discussion."* [US 6]

Still, teachers' responses that further involved the concurrent assessment of students' understanding were categorized as Responding (RP). Although the occurrence of RP strategies was minimal (**Table 3**), some teachers considered the evaluation of students' understanding to be important in their instruction as follows,

*"Give a formative assessment to identify where each student's deficits lie. Taylor further discussion based on the results in smaller groups, differentiated by their specific deficit; diagrams, tutorials, break down process into steps with visuals and evaluate student writing to determine what they don't understand."* [UT 74]

**Table 3.** Teachers Instructional Approach towards Misconceptions

| | Total | | US | | Korea | |
|---|---|---|---|---|---|---|
| **Approach** | **Number** | **%** | **Number** | **%** | **Number** | **%** |
| **Content-focused** | **526** | **74%** | **221** | **65%** | **304** | **82%** |
| Re-teaching (RE) | 61 | 9% | 22 | 6% | 39 | 11% |
| Concept Explanation (CE) | 161 | 23% | 47 | 14% | 114 | 31% |
| Demonstrating (DR) | 304 | 43% | 152 | 45% | 151 | 41% |
| **Student-focused** | **182** | **26%** | **118** | **35%** | **65** | **18%** |
| Relating (RL) | 41 | 6% | 22 | 6% | 19 | 5% |
| Activity (AT) | 135 | 19% | 93 | 27% | 43 | 12% |
| Responding (RP) | 6 | 1% | 3 | 1% | 3 | 1% |
| | 708 | 100% | 339 | 100% | 369 | 100% |

The common trend in the overall prevalence of content-focused approaches compared to student-focused ones seems to be more evident for the Korea teachers (Column "US" and "Korea", **Table 3**). While technically US teachers do tend to use a more content-focused approach to teaching (65% versus 35%), their use of student-focused teaching is still higher than their Korea counterparts (82% vs. 18%). In addition, while demonstration is the most frequently observed category for both US and Korea teachers, it is the prevalence of concept explanation that causes Korea teachers to side more heavily with content-focused approaches overall. Lastly, within student-focused approaches, both countries show the more frequent use of *activity*, with the minimal occurrence of *responding* category.

## Connecting Teacher Perceptions and Instructional Approaches

Lastly, in order to examine how teachers' perceptions of misconception are related to their instructional strategy, each perspective was paired with its corresponding strategy. In accordance with the previous reports on the prevalence of content-focused perspective and strategies, pairings between the content-focused strategies (**Figure 2** (a), indicated as blue bars) were predominant overall, regardless of how the teacher perceives students' misconceptions.

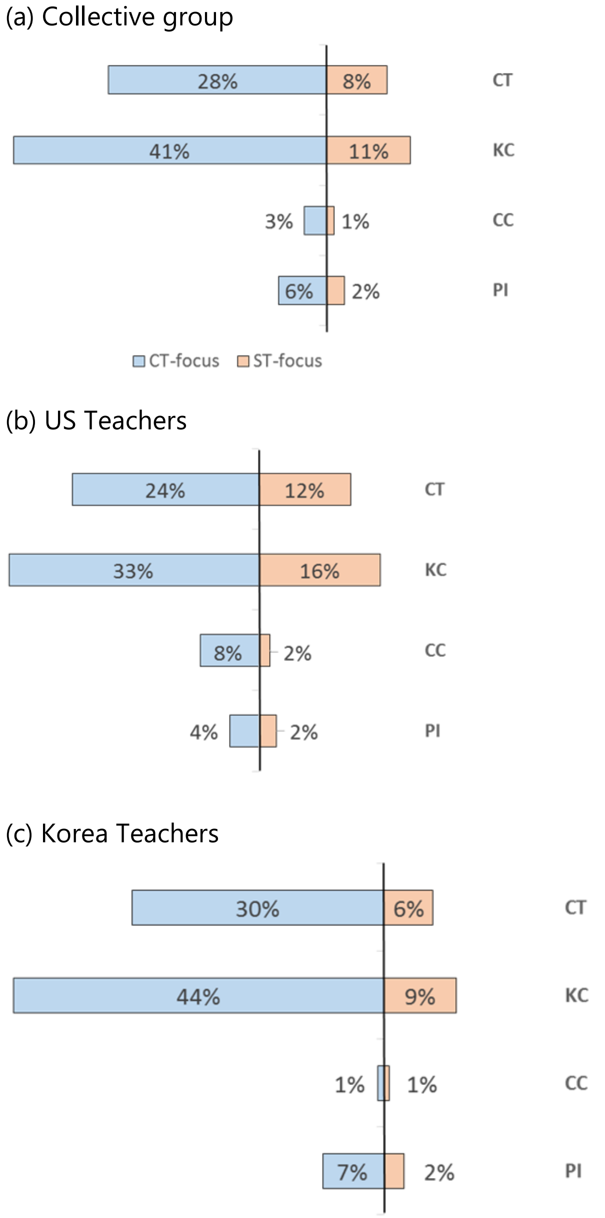


**Figure 2.** Connecting Teacher Perceptions and Instructional Approaches.

Still, various combinations address various aspects of students' misconceptions (detailed data reported in the Appendix E). For instance, when teachers held a content perspective (CT), demonstrating was the most frequently parried strategy, followed by concept explanation strategy, and others. Within CT Perspective, frequent pairing with content-focused strategies was most evident in CT-T, followed by CT-A, and then CT-D. CT-A and CT-D perspectives were mostly paired with Demonstrating strategies while CT-T perspective was frequently paired with both Concept Explanation and Demonstrating strategies.

Furthermore, increased parings with concept explanation strategy were observed when teachers hold knowledge construction (KC) perspective, of which a common example would be,

> *It would be most difficult for students to understand, since they seem to have trouble understand the role of light* (KC-C) – *I would explain that sunlight is required for the reaction, so carbon dioxide will not be used unless sunlight is present.* (CE) (UT 70)

As such, approaching students who have confusion in connecting ideas (KC-C) or inherent misconception (KC-M) seemed to involve concept explanation or demonstrating. Lack of relevant information (KC-L) was most frequently paired with demonstrating. In most cases, overall, targeting the specific knowledge structure was accompanied by either explaining the concept in detail or by providing different methods of representing ideas. In some cases, however, pedagogical reasoning behind selecting specific approaches was not readily evident or insufficiently elaborated. For instance, UT 46 noted that misconception arose because "*the word photosynthesis suggests that light is always necessary*" and that s/he intends to approach the issue by "*review concept maps, have students compare their maps to other students.*"

In regards to the overall comparison between the two countries, pairings were more evenly distributed for US teachers than Korea teachers. As shown in **Figure 2** (b) and (c), Korea teachers relied more heavily on content-focused approaches in addressing students' knowledge construction process.

## Discussions and Implications

To summarize, teachers tended to perceive students' misconceptions in consideration of the concept or from a knowledge construction perspective. In particular, Korea teachers were more sensitive in acknowledging the necessary linkages within the knowledge structure of students' misconception. Beyond addressing the challenges associated with the nature of concept itself, assisting students' learning process by directly targeting students' knowledge construction process requires more sophisticated understanding of the concept. Among many possible attributing factors, concentration on the development of content knowledge in teacher education system in Korea may account for Korea teachers' awareness of the materials. Besides, concentrating on fostering students' knowledge development within a curriculum that is almost identical across the schools in Korea may be closely related to why Korea teachers hardly attributed curriculum – which is beyond the their agency- as the source of students' misconception development.

In respect to the pattern for how science teachers approach students' misconceptions, it was similar across the two countries that the content-focused approach was more predominant than the student-centered approach. It is interesting to note that while teachers' perceptions of student misconceptions arise mostly from students' knowledge construction process, teachers intend to implement instructional strategies with a focus on the content rather the students who are constructing the knowledge around the topic. Even within the student-focused approaches, dynamic and interactive nature of the environment expected of a constructivist classroom could rarely be detected in teachers' responses. While engaging students in various activities could be one way to provide an interactive learning environment, diagnosing and responding to students' learning processes appeared to be an area that needs further attention.

In a similar vein, student-focused approaches in this study are closely aligned with the constant promotion of reform efforts to adopt more students' involvement in the learning process (e.g., NRC, 1983; NRC, 1990; Michael & Modell, 2003). In this respect, heavy reliance of re-teaching and demonstrating in content-focused approaches further necessitates how to incorporate the roles of students for effective teaching. The concern for non-shifting environment towards involving promoting students' constructive learning process in teachers' practice in Korea had previously claimed by Lee and Fraser (2002) that "while constructivist principles have been consistently emphasized in the science curriculum since 1982, actual practices in the classrooms in Korea have been dominated by teacher-centered, lecture-type instruction" (p.1). In the similar sense, relatively restricted environment in terms of involving student participation for Korea classrooms was also reflected in this study by the limited number of methods of activities teachers intends to provide for their instructional approaches. That is, as compared to various activities US teachers provided in their responses, only a limited pool of strategies were re-iterated in Korea teachers' responses. While caution should be made in evaluating teachers' knowledge on various activities from this study's findings, it still warrants explorations to examine why such diversity could not be observed in Korea teachers. For example, are the frequently mentioned strategies are based on their professional judgement, or, does a particular classroom environment setting unique to each country impact the extent to which the teachers can adopt diversified instructional strategies?

It also supports the claim made by Campbell et al. (2010) that "little consideration for students' prior knowledge of how lessons were designed, little science process emphasized that might empower students to explore and create ideas based on concrete experiences, and little emphasis on communication occurring among students in their country" (p.160). While translation of constructivists' perspective to its practice is challenging enough, teachers' favorable appreciation of content-oriented strategies warrants further research on examining the basis for making such pedagogical decisions. Furthermore, the effectiveness of providing various hands-on learning opportunities for students, which were classified as student-focused strategies, is still in question. Thus, it appears that more empirical research studies are warranted to further explore how effectively these student-centered strategies could be enabled.

Lastly, there exist some limitations of the study given the nature of the data source used for the analysis. First, the findings are restricted to the topic of photosynthesis for its conceptual focus. Content-oriented patterns may have resulted from the heavy content-loaded curriculum imposed around the topic of photosynthesis. Also, in regards to examining teachers' instructional strategies towards students' misconceptions, self-reported constructed responses can only function as an indirect measure of teachers' actual pedagogical decisions in practice. The combination of other data sources, such as classroom observations and teacher interviews, may assist in providing richer descriptions of the instructional practice and further to design effective professional assistance in promoting student involvement in the classroom setting.

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# APPENDIX

## A. Example of a scenario set in the survey

**1. Ms. Hammer was wrapping up the lesson on photosynthesis by writing the following summary equation on the board:**

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Sunlight, Chlorophyll}} 6\ O_2 + C_6H_{12}O_6\ \text{(glucose)}$$

Ms. Hammer led a discussion about the equation to determine what students did and did not understand about photosynthesis and this is what they said:

| |
|---|
| April: Sunlight is necessary to warm the plants to do photosynthesis. During photosynthesis, plants absorb heat energy from the sun.<br>Bill: Right, that takes place in the green pigments in chloroplast. Then heat energy is converted to chemical energy, producing glucose, when there is no light.<br>Cindy: Glucose is also absorbed, along with other nutrients, from the soil through roots. They serve as food, helping the plants to grow. |

1) The following is Ms. Hammer's analysis of the students' discussion. Do you agree with her assessment? (Mark *Yes* or *No* for each item below.)

| | | Yes | No |
|---|---|---|---|
| a) | April understands the role of sunlight in photosynthesis. | ☐ | ☐ |
| b) | Bill understands when photosynthesis occurs in plants. | ☐ | ☐ |
| c) | Both April and Bill misunderstand the type(s) of energy involved in photosynthesis. | ☐ | ☐ |
| d) | Cindy understands various appropriate sources of glucose for plants. | ☐ | ☐ |

2) In your experience, among the concepts listed in the above question [(i.e., a) -d)], which concepts have you noticed most students have difficulty to understand? Why do you think that concept is difficult for students to learn?

3) What strategies do you usually use (or would you like to use) to help students better understand the concept that you selected in question 2)?

## B. Demographics of the Participants

| US | | Number | Percentages | Korea | | Number | Percentages |
|---|---|---|---|---|---|---|---|
| **Total** | | **85** | **100%** | **Total** | | **81** | **100%** |
| **Gender** | Male | 38 | 45% | **Gender** | Male | 19 | 23% |
| | Female | 47 | 55% | | Female | 62 | 77% |
| **Age** | 20-29 | 12 | 14% | **Age** | 20-29 | 26 | 32% |
| | 30-39 | 31 | 36% | | 30-39 | 34 | 42% |
| | 40-49 | 17 | 20% | | 40-49 | 15 | 19% |
| | >50 | 25 | 29% | | >50 | 6 | 7% |
| **Teaching Experience** | 1-5 | 14 | 16% | **Teaching Experience** | 1-5 | 33 | 41% |
| | 6-10 | 26 | 31% | | 6-10 | 23 | 28% |
| | 11-20 | 23 | 27% | | 11-20 | 14 | 17% |
| | >21 | 22 | 26% | | >21 | 11 | 14% |
| **Teaching Subject** | Biology | 59 | 69% | **Teaching Subject** | Biology | 70 | 86% |
| | Chemistry | 38 | 45% | | Chemistry | 14 | 17% |
| | Physics | 26 | 31% | | Physics | 10 | 12% |
| | Anatomy | 34 | 40% | | Earth Science | 8 | 10% |
| | Earth Science | 23 | 27% | | General Science | 55 | 68% |
| **School Level** | Middle | 13 | 15% | **School Level** | Middle | 21 | 26% |
| | Junior-High/High | 75 | 88% | | High | 60 | 74% |

## C. Codebook: Teacher Perceptions towards Misconceptions

| | | |
|---|---|---|
| **Concept (CT) Perspective** | | Teachers perceive students' misconception from a pure content perspective, such as the abstract nature of the topic, topic difficulty or vocabulary issues. |
| | CT-A | Abstractness nature of the concept<br>Example. *It is probably hard to understand for some because the idea is so abstract and you can't see it happening.* |
| | CT-D | Difficulty of the topic to conceptualize<br>Example. *Identifying the reactants and products of photosynthesis because it is very complex with both the light and dark reactions.*<br>Example. *It is hard for them to learn b/c it is such a difficult series of chemical reactions.* |
| | CT-T | Terminology or the naming used in the concept<br>Example. *It's difficult because of the terminology we use to differentiate the different steps involved in photosynthesis* |
| **Knowledge Construction (KC) Perspective** | | Teachers perceive students' misconceptions in terms of knowledge construction process, by taking into account students' lack of background knowledge, difficulty in making connection or pre-established misconceptions that is related to the topic. |
| | KC-L | Lack or absence of a related/necessary content.<br>Example. *They have not studied redox reactions and often times this is the first chemical reaction they've seen which has multiple steps in it.* |
| | KC-C | Confusions occurring when connecting the ideas mostly due to weak understanding on relevant information<br>Example. *Students struggle with the chemistry and piecing all of the details together.* |
| | KC-M | Inherent misconceptions or inaccurate/inappropriate way of thinking students hold when they are learning the content.<br>Example. *I think student think of photosynthesis and respiration as opposites so do not understand they can take place at the same time.* |

| | |
|---|---|
| **Curriculum (CC) Perspective** | Teachers perceive students misconceptions as a result of a curriculum issue that is vertically established.<br>Example. *I think this can be a difficult reaction to understand without the Chemistry concept that this is ultimately a "reverse combustion" reaction. They could get this if they had the Chemistry concept previously mastered. Chemistry doesn't come until their junior year.* |
| **Pedagogical/ Instructional (PI) Perspective** | Teachers perceive students' misconceptions by taking into pedagogical considerations such as instructional issues.<br>Example. *Many teachers / textbooks do not discuss light/dark reactions in depth or at an appropriate developmental level.* |

## D. Codebook: Teachers' Instructional Approach towards Misconceptions

| **Content-focused** | Teachers approach the misconception with specific focus on the content without any involvement of the students |
|---|---|
| Repeating/Emphasizing (RE) | Teachers re-teach the concept without any significant change from earlier attempt.<br>Example. *We go over the info again and again; Stress that plants are living things* |
| Concept Explanation (CE) | Specifically aim to target certain concepts, modifying *what* of the content.<br>Example. |
| Demonstrating (DR) | Teachers demonstrate an idea/concept related to the misconception in different ways; does not involve students' participation<br>Example. *Demonstrate the importance of a catalyst in a reaction. Then use diagrams and flow chart demonstrating the purpose of sunlight* |
| **Student-focused** | Teachers approach the misconception with varying degrees of student consideration |
| Relating (RL) | Teachers relate an idea/concept related to the misconception with students' prior knowledge/experience.<br>Example. *I would also check to see if the nitrogen or carbon cycle had been part of their previous formation/prior experience.* |
| Activity (AT) | Teachers provide opportunities for the students to be actively involved in an activity, either hands-on or group discussion<br>Example. *I would ask the kids to mix carbon dioxide gas (the baking soda vinegar reaction) and oxygen gas (shaking hydrogen peroxide) into a container, and heat it with a sunlamp to see if sugar formed.* |
| Responding (RP) | Teachers show openness to students' response or feedback<br>Example *[after the activity, students should] explain to me why each is that form.* |

## E. Connecting Teacher Perceptions and Instructional Approaches. Values indicate the frequencies of each perspective-strategy pair (percentages of major categories shown in parenthesis).

| | | **Strategy** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Perspective** | **CT-focus** | **RE** | **CE** | **DR** | **ST-focus** | **RL** | **AT** | **RP** | **Total** |
| Collective Group | **Total** | **328** | 35 | 115 | 178 | **93** | 29 | 60 | 2 | **421** |
| | **CT** | **119 (28%)** | 13 | 31 | 75 | **33 (8%)** | 14 | 19 | 0 | **152** |
| | CT-A | 40 | 4 | 6 | 30 | 12 | 5 | 7 | 0 | 52 |
| | CT-D | 27 | 2 | 5 | 20 | 13 | 4 | 9 | 0 | 40 |
| | CT-T | 52 | 7 | 20 | 25 | 8 | 5 | 3 | 0 | 60 |
| | **KC** | **171 (41%)** | 17 | 69 | 85 | **46 (11%)** | 11 | 34 | 1 | **217** |
| | KC-L | 30 | 2 | 9 | 19 | 11 | 4 | 7 | 0 | 41 |
| | KC-C | 86 | 10 | 37 | 39 | 13 | 1 | 12 | 0 | 99 |
| | KC-M | 55 | 5 | 23 | 27 | 22 | 6 | 15 | 1 | 77 |
| | **CC** | **12 (3%)** | 1 | 4 | 7 | **4 (1%)** | 1 | 3 | 0 | **16** |
| | **PI** | **26 (6%)** | 4 | 11 | 11 | **10 (2%)** | 3 | 6 | 1 | **36** |
| US Teachers | **Total** | **90** | 5 | 26 | 59 | **42** | 12 | 30 | 0 | **132** |
| | **CT** | **32 (24%)** | 2 | 2 | 28 | **16 (12%)** | 5 | 11 | 0 | **48** |
| | **KC** | **43 (33%)** | 1 | 19 | 23 | **21 (16%)** | 6 | 15 | 0 | **64** |
| | **CC** | **10 (8%)** | 1 | 3 | 6 | **2 (2%)** | 1 | 1 | 0 | **12** |
| | **PI** | **5 (4%)** | 1 | 2 | 2 | **3 (2%)** | 0 | 3 | 0 | **8** |
| Korea Teachers | **Total** | **238** | 30 | 89 | 119 | **51** | 17 | 32 | 2 | **289** |
| | **CT** | **87 (30%)** | 11 | 29 | 47 | **17 (6%)** | 9 | 8 | 0 | **104** |
| | **KC** | **128 (44%)** | 16 | 50 | 62 | **25 (9%)** | 5 | 19 | 1 | **153** |
| | **CC** | **2 (1%)** | **0** | **1** | **1** | **2 (1%)** | **0** | **2** | **0** | **4** |
| | **PI** | **21 (7%)** | **3** | **9** | **9** | **7 (2%)** | **3** | **3** | **1** | **28** |