Understanding Middle School Teachers' Processing of Student-Generated Resources in Science Classrooms

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Abstract: Teachers constantly encounter various responses generated by students in the classroom. These responses, which can be regarded as instructional "resources" that have potential value for facilitating students' deep learning, are not fully used in teachers' everyday practice. By proposing the notion of "student-generated resources" (SGRs) and adopting a "resources use" rather than sociolinguistic perspective, this study investigates what SGRs are there in the classroom and how teachers process them. Based on classroom observations, we identify five types of SGRs. Following the "perceive–interpret–mobilize" processing flow, teachers demonstrate three processing results (utilize, feedback, and abandon). Further, we identify three approaches of teachers' utilization of SGRs and five approaches of their feedback to SGRs. Our findings suggest that teachers tend to give feedback to SGRs rather than utilize them as resources. This study broadens theoretical landscape about classroom resources and helps teachers take full advantage of SGRs in empowering students' learning.

Introduction

The classroom is a place full of dynamic and unpredictable events, such as students' answers to teachers' questions and questions raised by students. Teachers' processing of students' responses shapes and features teacher-student interaction as well as instruction and learning in the classroom. The structure and content of teacher-student interaction is the focus of studies following the discourse analysis perspective (Frances, 2002). The famous IRE/F (Initiate-Response-Evaluate/Feedback) framework, first proposed by Mehan (1979) and Sinclair and Coulthard (1975) and revised by Lemke (1990), has dominated this field for a long time (Louca, Zacharia, & Tzialli, 2012). However, IRE/F-based analyses fail to capture the complexity of the discourse with regards to what the students are contributing, most of these studies view teacher's responses to students as relatively passive reactions. Little research moves forward to trace effects of teacher's responses and their potential influence on consequential instructional activities.

Our study adopts an alternative perspective that views student-generated events as potential instructional resources, termed here as student-generated resources (SGRs). Specifically, in this study, SGRs include students' responses (especially non-normative answers) to teachers' questions as well as students' ideas, questions or experiment findings expressed in class. We not only focus on how teachers deal with SGRs, but also explore their perceiving and interpreting of SGRs, mobilizing and integrating other related resources with SGRs, and the final utilizing of them. In line with Chin and Osborne (2008), we viewed students' questions as "a potential resource." Such resource not only helps students in the learning process, but also serves useful functions as a pedagogical tool for the teacher. The resource perspective expands our vision from teachers' in-the-moment decision making procedure (Erickson, 2001) to the entire processing flow, providing us with a more systematic view of teachers' classroom practice.

Our perspective draws on the emerging research field of curriculum (resource) use (Cohen, et al., 2003; Remillard, 2005). The underlying assumption of this field is that teachers are central players in the process of transforming curriculum ideals, captured in the form of mathematical tasks, lesson plans and pedagogical recommendations, into real classroom events (Lloyd, Remillard, & Herbel-Eisenmann, 2009). Over the last decade, studies in this field have grown tremendously, generating several enlightening frameworks (e.g. Brown, 2002; Gueudet & Trouche, 2012), enhancing our understandings of how teachers use curriculum resources. Research in this field broadens researchers' understandings of curriculum materials or resources, not only textbooks, instructional guides and digital learning environments as well as interactions among teacher, student and curriculum are also regarded as an important origin of curriculum resources.

By adopting the resource perspective, we try to bridge the fields of teacher-student discourse interaction and of curriculum (resource) use. Building on the intersection point of the two fields, our study tries to answer the following questions:

1. What SGRs are there in middle school science classrooms?
2. How do teachers process these SGRs?

Theoretical framework

Teacher-student discourse interaction

Following a sociolinguistic perspective (Carlsen, 1991; Frances, 2002), Teacher-student discourse interaction studies has stressed the importance of classroom discourse for teaching and learning. The main approaches for studying teacher discourse followed primarily the Initiation–Response–Evaluation (IRE) or Initiation–Response–Followup or Feedback (IRF) structure (Lemke, 1990). These approaches have received criticism, especially regarding the focus of research approaches in using IRE exclusively on a teacher's role in initiating and maintaining a conversation. Research needs to provide a more coherent framework for studying teacher discourse in relation to student discourse (Aguiar, Mortimer, & Scott, 2010; Cazden, 2001; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001).

Studies guided by other perspectives have broadened the vision of classroom discourse. Scott (1998) defined the notion of "teacher responsiveness" including three elements: 1) monitoring (monitor the present performance of students), 2) analyzing (analyze the nature of any differences between present performance and the target performance), and 3) assisting (respond with an appropriate intervention to support students).

Louca, Zacharia, and Tzialli (2012) argued that it might be more useful for the research community to have a framework that focuses on student contributions during the conversation and the teacher decisions and responses based on those contributions. Therefore, they developed a framework for investigating classroom discourse by focusing more broadly on what the teacher responds to, how she responds, as well as the process of deciding how to respond. This framework includes *Identification*, *Interpretation—Evaluation*, and *Response*. The Identification part concerns what the teacher responds to (student discourse contributions), the *Interpretation—Evaluation* part concerns how the teacher *interprets* and *evaluates* students' discourse contributions, while the Response part concerns how the teacher responds to students' discourse contributions.

Teachers' use of curriculum (resource)

For researchers in this field, "use" means a variety of interrelated pedagogical activities, including how teachers engage or interact with these resources as well as how and the extent to which they rely on them in planning and enacting instruction, and the role resources play in teachers' practice. (Lloyd, Remillard, & Herbel-Eisenmann, 2009)

Research on curriculum (resource) use (e.g. Cohen, et al., 2003; Remillard, 2005; Gueudet & Trouche, 2012; Jin, et al., 2015) proposes that teachers *perceive* and *interpret* what happened in the classroom before they draw upon resources in the subsequent instruction. Hammer (1997) argued that teachers should coordinate relevant resources to achieve instructional goals before they have the opportunity to implement instruction. Brown (2002) proposed the notion of "pedagogical design capacity" to characterize teachers' capacity to perceive, interpret and mobilize curriculum resources in the pursuit of desired outcomes. Adler (2000, 2012) proposed to turn the noun word resources into a verb "re-sources", emphasizing the nature of teacher's use of curriculum materials is a reconstruction procedure. Similarly, Gududet and Trouche (2012) also pointed out that through a procedure of what they called instrumentalization, teachers transform external resources (e.g. textbook, software, unpredictable student responses) into "lived" resources applicable in their own classroom contexts.

A framework for analyzing teachers' processing of SGRs

By reviewing literature, we found an intersection point of the above two fields: they both have interests in teachers' processing flow of SGRs. Viewing students' responses as instructional resources, we constructed our framework for analysis of teachers' processing of SGRs by integrating the key procedures derived from widely used curriculum (resource) use research (e.g. Brown, 2002) and teacher-student discourse interaction research (e.g. Louca et al., 2012), as shown in Figure 1. The verbs "perceive-interpret-mobilize" in rectangles defined three key steps of teachers processing of SGRs. In curriculum (resource) use research, "perceive" means teachers' awareness of the resource that has potential value for instruction (Brown, 2002). Louca et al named the similar step that teachers noticed students' verbal responses as identification (Louca et al., 2012). "Interpret" refers to teachers' evaluation of SGRs and current contexts so as to decide whether or not to use SGRs in the next step. If teachers decide to use a certain piece of resource, they need to choose and integrate other related resources. This step is named "mobilize". For instance, the teacher refers to his/her PCK to give a comment to one student's response to an open-ended question or gives a clear explanation to one student's question about the experiment design. As a result, at the end of the processing procedure flow, there are three different types of processing results, labeled as *utilize, feedback and abandon*. Specifically, our framework illustrated branches (not perceived, not decided to use) in the processing flow and three types of processing results (utilize, feedback and abandon), these details were mentioned or implied in the two fields but not thoroughly discussed. We hope to promote understanding of these details with our framework.

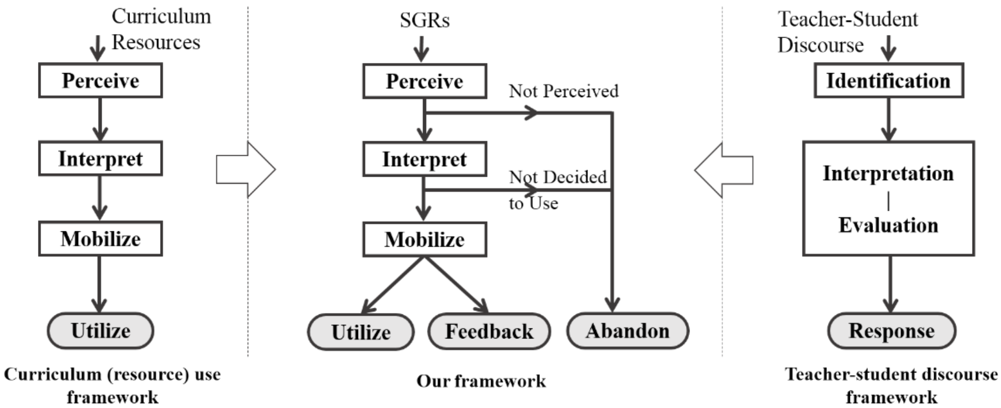

Figure1. A Framework for analyzing Teachers' Processing of SGRs.

Methods

Participants and context

This study took place in a middle school located in downtown Shanghai. Two experienced teachers were purposefully selected from 4 science teachers in that school according to criteria proposed by Berliner (1994, 2004) they had taught science in school for more than 7 years, and 2) their achievement in science teaching had been recognized by both principals and colleges. We chose experienced teachers in our study because they have well-developed professional competences and more stable teaching behaviors, which would enable us to capture the patterns and features of teachers' processing of SGRs. Teacher A had 19 years teaching experience while Teacher B had 8. They taught science for 7th graders and 6th graders respectively.

According to *Shanghai Middle School Science Curriculum Standards*, Science, as a subject, is designed for students in grade 6 and 7 and aims at developing students' comprehensive science understanding and knowledge before taking physics, chemistry, life science and geography in grade 8. After discussing with both teachers, we finally chose "photosynthesis and respiration" for Teacher A and "features of living things" for Teacher B. Both teachers said they had interest and confidence for teaching their own topic. This context was helpful for us to capture abundant SGRs and explore teachers' sophisticated processing of them. Each topic included 45 minutes of classroom instruction and 45 minutes of laboratory experiment, and was taught by one teacher in two classes respectively. Students in all the classes had similar performances and achievements in science learning.

Data sources

Eight lessons (each topic included two lessons, one teacher taught for two classes repeatedly) were recorded using video camera. Immediately following each lesson, short interview (3-5 minutes) were conducted and recorded to help us verify some ideas about teachers' teaching behaviors we observed. All of the video and audio records were transcribed. We used Nvivo 10 to manage data and conduct analysis.

Data analysis

Categories of SGRs

We first viewed all the lesson videos and identified every piece of SGR according to the definition mentioned above. Then by using open coding method (Glaser & Strauss, 1967), we labeled and categorized each piece of student-generated resource. We then looked through all labels and verified their fitness. Finally, we adjusted and refined the following list (see Table 1) to develop codes for categorizing SGRs.

Table 1: Categories of SGRs

Category	Description	Typical Example
NR-Close	Non-normative Response to teacher raised Close-ended question	T: Where does respiration take place? S: In our lungs.
NR-Open	Non-normative Response to teacher raised Open-ended question	T: Do you know other common features of animals? S: Animals live together.
RR-Open	Reasonable Response to teacher raised Open-ended question	T: Give me an example of animal's adaption to environment. S: Bears hibernate in winter
SQ	Student raised Question	A student asked Teacher A what is the black thing in the bottom of the test tube.
SE	Student Experiment phenomenon or problem	A student reported his snail showed no reaction to light.

*As correct answers to close-ended questions are predictable, this kind of student responses was not considered as *generated* resource in our study.

Procedure of teacher's processing SGRs

The theoretical framework mentioned above served as a reference for analyzing teacher's processing procedure of student-generated resources. Meanwhile, we kept open-minded and sensitive to any evidence emerged from the data that might bring revision to the theoretical framework. After a similar process mentioned above, we developed codes to identify different processing stages. (Table 2)

Table 2: Stages of teachers' processing SGRs

Stage	Description	Typical Example
Perceived	The teacher noticed a piece of student-generated resource.	When discussing "whether coral is animal or plant", some students said "animal" others said "plant", We observed that both were noticed by Teacher B.
Not Perceived	We noticed a piece of resource but no evidence showed that the teacher noticed it.	(not occurred in the lessons we observed)
Decided to use	The teacher showed response to a piece of resource she noticed.	Teacher B asked students who said "coral is animal" to explain their reasons.
Not decided to use	The teacher noticed a piece of resource but showed no response to it.	Teacher B noticed some students said "coral is plant", but never asked them to explain.
Utilized	The teacher made use of the resource in the following instruction.	A student asked "why should we first put the plant in a dark room for 24 hours", then Teacher A used it as a question to ask the class.
Feedback	The teacher only gave the student(s) some kind of feedback	When a student replied "chlorophyll" for the question on the products of photosynthesis, Teacher A said "No, chlorophyll is a kind of matter of the plant itself."

Results

Categories and frequencies of SGRs

According to the codes of SGR categories, we finally identified 36 pieces of SGRs in Teacher A's classes and 26 pieces of SGRs in Teacher B's classes. (Considering the same lesson repeated in different classes, SGRs observed in different classes with both same content and teacher processing mode are counted as one single resource).

Figure 2 shows the frequencies of different types of resources generated by students in science class. Overall, the majority of SGRs (Teacher A: 89%, Teacher B: 88%) are students' responses to teachers' questions (including NR-Close, NR-Open, RR-Open). In Teacher A's class, we identified all five types of SGRs (36 pieces), of which up to two-thirds were NR-Close type (22 pieces), while in Teacher B's class, there's no SQs, RR-Open type occupies 50% (13 pieces) of all SGRs in her class.

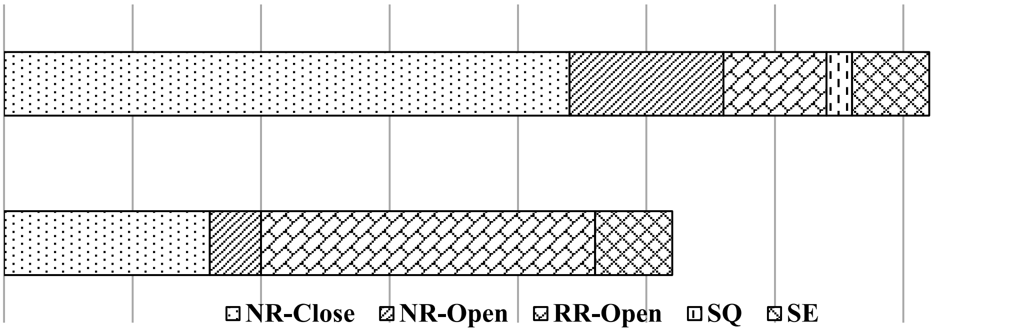

Figure2. Frequencies of different categories of SGRs in two teachers' classes.

Procedure and results of teachers' processing SGRs

By coding teachers processing stages of SGRs, we found teachers basically followed the "perceive-interpret-mobilize" procedure and both teachers could perceive and interpret all the SGRs. In terms of the processing results, teachers have similar preferences. They abandoned only two pieces of SGRs each, all the four pieces of SGRs belong to NR-Close category. As shown in Figure 3, when science teachers successfully incorporated other resources to mobilize the SGRs, they might not *utilize* them. Rather, they were more likely to give *feedback* for the SGR's own sake. For instance, a teacher might directly correct students' non-normative answers or only tell students whether their answers are right. Both Teacher A and Teacher B gave lots of feedback to SGRs in their science class, accounting for 61.1% and 69.2% of all the processing results respectively. However, Teacher A utilized one third of SGRs in the class and Teacher B utilized less than one quarter of all the SGRs. (see Figure 3, width of the arrow lines indicates quantity of SGRs in the branches)

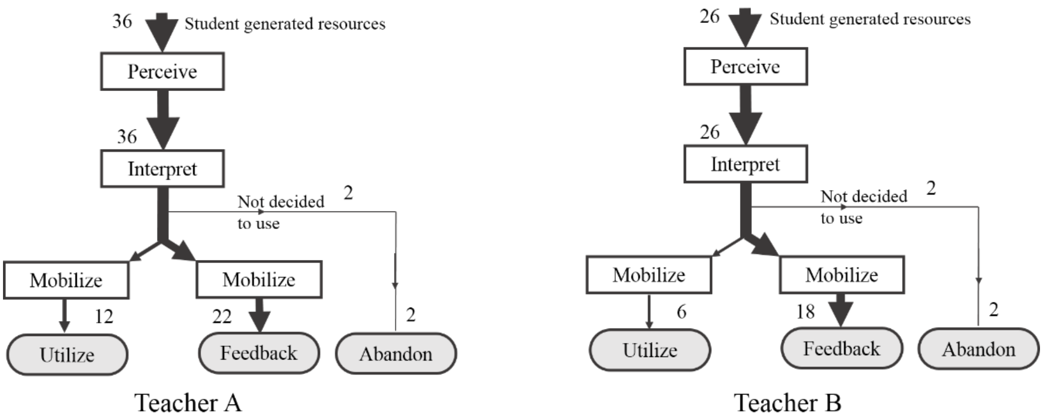

Figure 3. Teachers' processing flow of SGRs.

Distribution of utilization and feedback among five categories of SGRs

In general, teachers *decided to use* the majority of the SGRs regardless of their categories. Figure 4 illustrates the distribution of utilization and feedback among five different types of SGRs. We found that the two teachers *utilized* three of the five categories of SGRs: NR-Close, RR-Open and SQ. Both teachers could *utilize* NR-Close type of SGRs, of all the SGRs utilized by each teacher, NR-Close type of SGRs took 92% and 67% respectively. In terms of each type of SGRs, both teachers utilized more than one half of NR-Close type of SGRs in their class. In the contrast, neither NR-Open nor SE type of SGRs were utilized by two teachers.

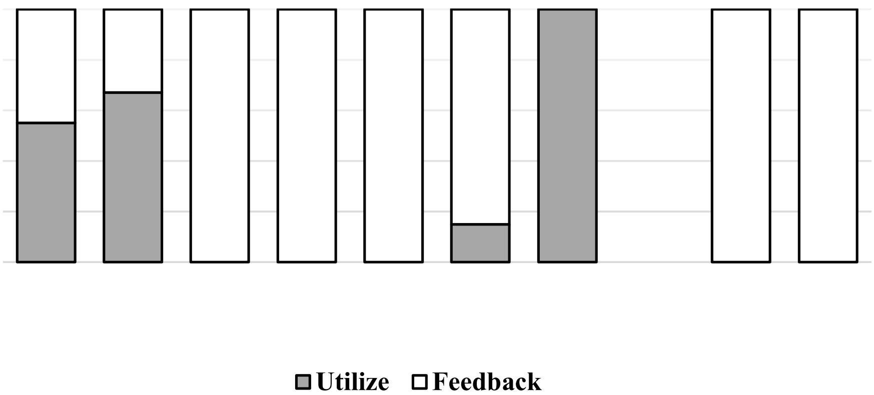

Figure 4. Distributions of utilization and feedback among five categories of SGRs.

Teachers' instructional approaches of utilization and feedback

When teachers *utilized* SGRs, they demonstrated 3 types of approaches: 1) *Testing* students' knowledge. For example, a teacher might repeat or revoice a student's answer and then ask the class "Do you agree on his/her idea?" or "Who can tell us what's wrong with his/her answer?". Teacher A used about 50% of the utilized SGRs to test students' mastery of knowledge, while for Teacher B, the proportion was 66.7%. 2) *Creating problem contexts*. For instance, a student proposed a question to Teacher A, "Why we should use alcohol to dissolve and remove chlorophyll in leaves? " Then Teacher A used this question as a trigger to engage all the students in thinking about the purpose of this key step in the experiment. Teacher A adopted this approach to process 42% of the utilized SGRs and Teacher B processed 33% of the utilized SGRs in his/her class. 3) *Extending content* in the textbooks such as introducing the concept of carbohydrate one the basis of students' responses. Two pieces of SGRs were utilized by Teacher A for content extension, while none utilized by Teacher B.

In terms of *giving feedback to* SGRs, both teachers had five specific ways to process them: 1) *Judge*, which means telling the truth of false was the most common way adopted by both teachers. In Teacher B's feedback to SGRs, 56% of them were processed in this way. For Teacher A, the proportion was 35%. 2) *Query*, referring to pointing out problems in students' responses. For example, a teacher asked the students who reported an experiment design that "could you guarantee that your design would prevent air from entering into the test tube?" Teacher A gave query to 1/3 SGRs received feedback, and Teacher B only processed one piece of SGRs in this way. 3) *Redirect* students' responses to the topic they were talking about. For example, one student argued that running away in the face of danger was a common feature of animals, and then teacher told her that "this is animals' adaptability to surroundings". Only one piece of SGR was redirected in Teacher A's class, while in Teacher B's class, 28% feedback were given by this approach. 4) *Correct*, that is, teachers correct mistakes or inaccuracy in students' responses. 5) *Explain*, namely give explanations to problems students encountered in doing their experiment. These two approaches were used seldom by both teachers.

Discussion and conclusion

This study shows that science classes were short of student initiated SGRs that might be of highly value for teaching utilization. The majority of SGRs were students' responses to teachers' questions (including NR-Close, NR-Open, RR-Open), whereas students initiated questions (including SQ and SE) were much less. This illustrates that students did not have sufficient opportunities or get necessary scaffolding to generate their own questions. This finding resonates with the results of many studies reviewed by Aguiar et al. (2010), which suggest that students' questioning is both infrequent and unsophisticated in the science classroom. Among students' responses, NR-Close type of SGRs took 56%. Though RR-Open SGRs occupy the second largest portion, most of those "open questions" can be characterized as directives, such as "Please give us an example of …" or "Tell me a phenomena in your everyday life that can illustrates …" which could be attribute to what Scott (1998) defined as "authoritative discourse", both of the teachers admitted that they made efforts to control students' utterance "on the expected way" to textbook topics. In that case, science teachers should be prompted to be less dominated in the class and give students more chances to propose their own questions that could be utilized as precious resources for enhancing students' science learning.

The analysis of teachers' processing procedure and results of SGRs reveals that the framework for analyzing teacher-student interaction in the curriculum (use) perspective could be available and practical for researchers. In our study, both teachers were able to notice and perceive all the SGRs, and they would automatically mobilize other resources they owned to utilize or give feedback to these SGRs. Besides, as we paid more attention to how teachers' responses influenced students' learning rather than the formal pattern itself, we identified specific instructional approaches teachers adopted in utilizing or giving feedback to SGRs. When teachers decided to utilize SGRs, they would flexibly use them to test, create problems situations or extend contents in the textbooks, which showed their general awareness of valuable SGRs and competences in processing SGRs. As classes moved, we found that students' understanding of science concepts or phenomena was enhanced. As a result, teachers' practical wisdom could contribute to further academic researches on the usage of SGRs, and then maximize the value of SGRs for students' science learning and understanding.

Our study also illustrates teachers' disabilities and weakness in dealing with these in-the-moment events. These would help us give more effective and targeted suggestions for teachers to optimize their processing of SGRs, thus empower students' science learning. The distribution of teachers' processing results among five categories of SGRs shows that most of the SGRs utilized by teachers were NR-Close type, while NR-Open, RR-Open and SE types of SGRs were not fully employed. It could be inferred that NR-Close type of resources were much easier for teachers' recognition and utilization with the least variability and uncertainty among all five types of SGRs. Therefore, we should develop teachers' abilities to address SGRs with high uncertainty and complexity.

In our view, giving feedback which was the most common processing result of SGRs, could also benefit students' learning. The key point lies in specific ways teachers adopt to approach the resources. In our analysis, the five types of feedback we identified and named in this study are similar with four different types of teacher feedback（Chin, 2006）. The analysis suggests that when teachers gave feedback to SGRs, they mostly judged the answers and pointed out directly whether the answers were right or wrong. While query regarded as higher-order cognitive feedback（Chin, 2006） took less than one quarter of all the pieces of SGRs. The effectiveness of feedback to SGRs was reduced because of the low-order cognitive ways teachers adopted. In this sense, we should facilitate teachers to give more high-order cognitive feedback in order to facilitate students' higher-order thinking.

In this study, we proposed the notion of "student-generated-resources" (SGRs). We argued that SGRs have much potential value for enhancing students' science learning if it can be made full use of by science teachers. We identified five types of SGRs and constructed a theoretical framework which links researches on curriculum (resource) use and teacher-student discourse interaction for analyzing teachers' processing of SGRs. In particular, we focused on teachers' processing results of different types of SGRs and their specific ways to utilize and give feedback to SGRs in the class. These findings helped us to figure out characteristics of teachers' processing of SGRs and thus give practical suggestions on teachers' instruction which may empower students' learning in science class.

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