Chemistry Teachers' Knowledge of Assessment in a Collaborative and Dynamic Learning Environment

Subject/Problem. There are few opportunities for teachers to hear their students think out loud, and when they do, they often miss the chance to capture learning moments and enact Formative Assessment (FA). FA describes the dynamic process of scaffolding students' learning by identifying assessment aspects for learning, and then responding to students' learning by addressing them actively (Bell & Cowie, 2001; Furtak & Thompson, 2016b; Sezen-Barrie & Kelly, 2017; Talanquer, Bolger, & Tomanek, 2015). The assessment for learning approach (AfL) incorporates many aspects of formative assessment, in which teachers create feedback based on students' activities and support students' learning (Casey & Amidon, 2020; Cowie, Harrison, & Willis, 2018). In this study, we use the framework of teachers' professional noticing to examine teachers` FA knowledge. This examination was conducted in a collaborative and dynamic learning environment. This process is mediated by the teacher's interpretation of these learning situations and includes teachers' noticing of domain-specific aspects as well as 21^{st} century skills, such as collaboration skills (Binkley et al., 2014; Pan, Lo, & Neustaedter, 2017) and listening skills (Authors & colleagues, 2021) which are unique to a collaborative and dynamic learning environment. Research on teachers' professional noticing can advance our understanding of teachers' knowledge and approaches to assessment. The teachers' professional noticing framework includes three sequential stages: noticing, interpreting, and acting by responding to students (Jacobs, Lamb, & Philipp, 2010; Murray et al., 2020). It is also related to the work of Furtak et al., (2016) in FA and the synthesis of the two frameworks: teachers' professional noticing and formative assessment.

Furtak and Thompson (2016), propose the following steps: (1) Teachers address students' responses and ideas, and recognize the scientific value in their ideas, (2) Teachers interpret students' responses and ideas, (3) Teachers assemble aspects they want to focus on and develop tools to address and scaffold their noticing. The following factors were taken into consideration when choosing this framework: (a) it addresses explicitly the process of designing and developing tools for supporting the implementation of FA and the practice of noticing, (b) it allows to connect the nature of noticing, interpreting, and acting during and after interacting with students, and (c) it enables the collaboration of teachers in several stages of design, analyze, and act on student responses. It also includes the feedback the teachers might provide to students to help them move forward in their understanding. Educational escape rooms are an example of a collaborative and dynamic learning environment. An increasing number of studies have examined the design and implementation of educational escape rooms, focusing on students' experiences and perceptions of such an activity (Gordon, Trovinger, & DeLellis, 2019; Ho, 2018). However, the aspect of teachers' knowledge of assessment in this learning environment has not been investigated. The main purpose of this research is to explore chemistry teachers' FA knowledge and approaches in a collaborative dynamic learning environment. The research questions are: in a collaborative and dynamic learning environment: (1) What do chemistry teachers notice as important to assess while observing their students? (2) What characterizes chemistry teachers' interpretation of their noticing?

This proposed research is significant since it will elaborate the theory about teachers' assessment knowledge and will establish theoretical foundations regarding FA in a collaborative, dynamic learning environments.

Design. Research Setting – This study took place in an innovative learning environment – a physical chemistry-based escape room. A physical chemistry-based escape room has been developed at our institution, to serve high-school chemistry teachers and students as an assessment method, see Figure 1. Audio-video systems allow teachers to watch and listen to students during and after activities. A one-week PD program called "Chemistry-based escape room as a pedagogical tool for assessment" was developed for teachers. The aims of the PD were:

Figure 1. The physical space of the chemistry-themed escape room (students consented to use the photo)

1. Experimenting in the escape room as learners, building a map of the escape room's puzzles, getting familiar with the chemistry content knowledge required, and the sequence and the structure of the room.
2. Learning about formative assessment, teachers professional noticing, and experiencing these through observations on students' while they are participating in the escape-room activity.
3. Discussing formative assessment and teachers' professional noticing in-relation to students' activity in the escape room in particular, and in teaching in general.

Research Participants – The participants in this study were 15 leading chemistry teachers in high school. 75% chemistry teachers were Jewish, 12.5 % Druze and 12.6 % Moslem and Christian. Their teaching experience ranges from four to over 29 years of teaching.

Research Tools and Methodology – A qualitative approach is employed in the present study. We adopted an exploratory approach to investigate a phenomenon in a situated context (Yin, 2009). Our situated context is the enactment of FA, through the noticing process in a chemistry-based escape room. Observation worksheets were collected from chemistry teachers during the PD program. This tool was designed to characterize teachers' noticing and interpretation of their students' thinking. A direct content analysis approach was used to analyze the data from teachers' observation worksheets (Hsieh & Shannon, 2005). We decided to analyze the construct of 'noticing' on two levels: (1) the dimension in which the noticing occurs, and (2) why the teacher chose to attend to this moment. In the initial coding round, researchers coded teachers' observation worksheets by searching for chemical thinking noticing, 21st century skills noticing, affective noticing, and developed initial codes (Binkley et al., 2014; Murray et al., 2020). To ensure trustworthiness of the coding scheme, two researchers independently coded a small portion of randomly selected occasions of noticing from each teacher's observation. Then researchers met to review and resolve any discrepancies in codes. To reach consensus on the suitability of the coding scheme and the coding of each chemistry teacher.

Analyses and Findings. We examined what teachers noticed and paid attention to when they observed student discourse in a chemistry escape room, a dynamic and collaborative learning environment (RQ1). Based on analyzing the teacher's observations, three noticing dimensions were identified: *Chemical thinking noticing, 21st century skills noticing, and Affective noticing.*

Figure 2 describes the number of learning situations in each noticing dimension. Then an extensive description of each dimension is presented.

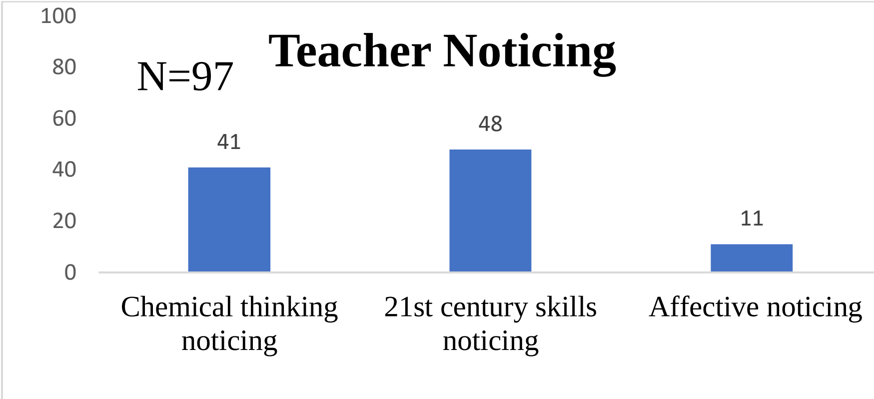

Figure 2. Number of teachers noticing statements (N=97) in the categories that emerged from the qualitative analysis of the teacher's observations

All together teachers reported on 97 noticing episodes they related to. It was found that 21st century skills noticing (N=48) was the most common dimension for chemistry teachers, for example, teachers focused on how the students collaborate while solving a puzzle at a chemistry-based escape room. *Affective* noticing was the least common dimension (N=11). Also, it was important for the teacher to observe how students employ chemical thinking in solving puzzles, in which students applied their knowledge to practical problems. We then characterized chemistry teachers' interpretation of their noticing (RQ2). We found that six patterns related to *Chemical thinking noticing* dimension, two patterns related to 21st century skills noticing, and four patterns related to *Affective* noticing, as illustrated in figure 3.

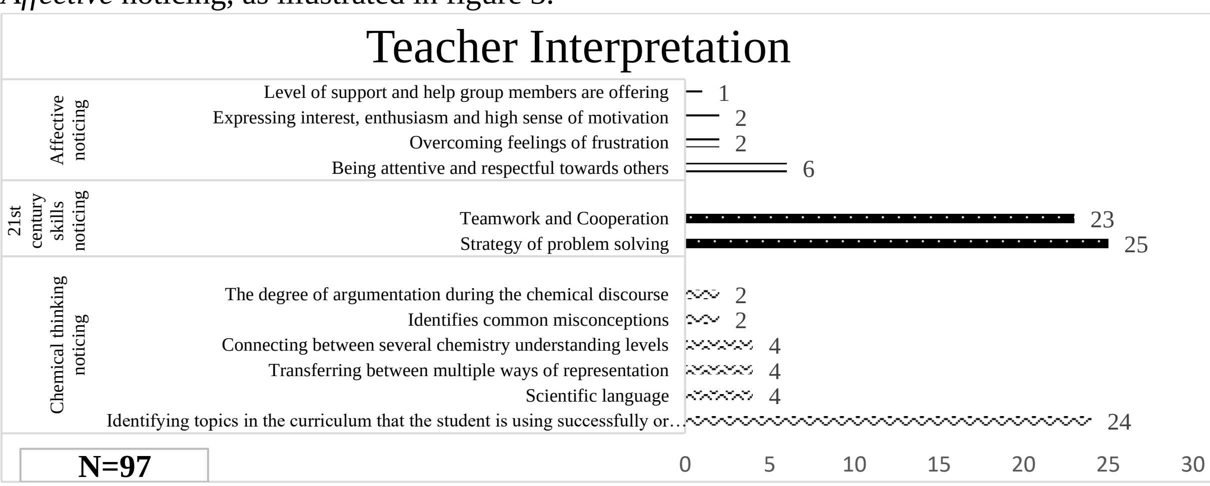

Figure 3. Number of learning situations (N=97) in the interpretation dimension that emerged from the qualitative analysis of the teacher's observations

According to the analysis, we found that: strategy of problem solving, teamwork and cooperation, and identifying topics in the chemistry curriculum that the student is using successfully or incorrectly, were the common characteristics of chemistry teachers' interpretation.

A detailed description of each characteristic related to the interpretation dimension of chemistry teachers is provided below:

A. Chemistry teachers' interpretation related to *Chemical thinking* noticing:

1. Identifying topics in the curriculum that the student is using successfully or incorrectly.

   In this interpretation - The teacher is trying to find out what chemistry content knowledge the student knows and can apply in solving the problem.

   For example: *"I wanted to check if the students recognize that it is an equilibrium reaction, whether they recognize the initial concentration of each substance and the concentration in the equilibrium state, and how according to these data they will be able to identify the chemical symbols".*

2. Scientific language - The teacher pays attention to students' chemical discourse and the chemical language they use while solving the problem. For example*: "The puzzle is easy, and they solve it relatively quickly. But the discourse is incorrect… the scientific language. In the matriculation test the scientific language is very important"*.

3. Transferring between multiple ways of representation - The teacher tries to find out whether students can understand the parameters given in the problem in one form of representation and solve it in a different one. For example*:" Using the key maze puzzle, we wanted to ensure students understood the task, that the process is not balanced, and that they understood how to transfer chemical representations to graphic representations".*

4. Connecting between several chemistry understanding levels - The teacher tries to find out whether students are using a variety of chemical understanding levels in their problem-solving process. For example*:" The solution includes reference to different levels of understanding in chemistry: micro and symbol. Throughout the solution, the students realized that there is a connection between the representation of the reaction at the microscopic level and the representation at the symbol level".*

5. Identifies common misconceptions - The teacher characterizes students' discourse by identifying common misconceptions they express during their problem-solving process. For example:" *There is a difficulty in understanding the difference between the molar mass of a substance and the molar mass of an atom".*

6. The degree of argumentation during the chemical discourse - The teacher focuses on the reasoning students make while raising an argument to their group members: Does the claim have a well-established and complete scientific explanation?

   For example*:" Many half-words were thrown around* [during their problem-solving process] *without exploring each argument in detail".*

B. Chemistry teachers' interpretation related to 21st century skills noticing:

1. Strategy of problem solving - The teacher tries to find out how strategically or with what generally school-based ways the student approached answering the puzzles, including comparisons to other students and to the teacher's approach. For example: *"In the puzzle of calculating the molar mass of sulfur, students guessed, that is, they guessed based on prior knowledge of chemistry instead of answering the puzzle based on the information given [and did not solve correctly]".*

2. Teamwork and cooperation - The teacher addresses the group's dynamic in several aspects: level of involvement of each group member in the problem-solving process, leadership and management roles, group structure - solving separately, all together or in small groups, reflectivity within the group. For example: *"Students were asked to scan spatial shapes of molecules in a molecular imaging puzzle by following the instructions, I wanted to examine how cooperation between learners and working according to instructions can enhance learning".*

C. Chemistry teachers' interpretation related to *Affective* noticing

1. Being attentive and respectful towards others - The teacher pays attention to the student's ability to be attentive and to listen to other group members regarding ways of solutions and offered strategy. For example*: "Personal characteristics of students can be identified: patience, no frustration, respect between students, no outbursts at one another's talking, listening".*
2. Overcoming feelings of frustration - The teacher pays attention to students' challenges and obstacles during the solving process with the aim of monitoring their feelings of disappointment and failure. For example: *"Though the student had some difficulty finding what to do with the task ... Although students faced difficulties and felt frustrated, they managed to overcome them".*
3. Expressing interest, enthusiasm, and high sense of motivation - The teacher pays attention to the level of excitement, motivation and interest of students while solving the puzzles. For example: "*The escape room is enjoyable... It is interesting to see the students' express interest and enthusiasm [for chemistry]".*
4. Level of support and help group members are offering - The teacher pays attention to the level of sharing of knowledge within group members, the support and help they offer each other. For example: *"While the student did not pay much attention to the data in the puzzles, he always offered suggestions for solutions and tried to help the others".*

Discussion and Contribution. In the escape room, students demonstrated their content knowledge, teamwork, and problem-solving abilities by solving chemistry puzzles. Results showed that chemistry teachers were engaged in identifying learning situations related to understanding students' thinking according to three dimensions: chemical thinking noticing (Murray et al., 2020), 21^{st} century skills noticing (Binkley et al., 2014), and affective noticing. Using the escape room chemistry environment as an aid to enact FA helped teachers to pay attention to student thinking as well as other dimensions related to their learning. The activity scaffolds teachers' use of FA and teachers' attended to their students' thinking, as reported in other studies (Casey & Amidon, 2020; Furtak & Thompson, 2016a; Sezen-Barrie & Kelly, 2017; Talanquer et al., 2015). In our study teachers also noticed how students worked in a group and related to one another and interpret their noticing in these dimensions as well. As Furtak and Thompson (2016) noted, teachers gain insight into student thinking through FA in their daily work, our study shows that it is important for teachers to listen to their students when assessing their learning, since they learn about students' content knowledge as well as their skills, such as teamwork and cooperation, arguments, team problem-solving. Also, our study shows that the collaborative and dynamic learning environment provided opportunities to advance teachers' knowledge of assessment for learning through professional noticing. Teachers' assessment of students' writing can contribute to their knowledge of noticing and inferring student understanding from students' writing (Talanquer et al., 2015). Our study advances the field by showing how teachers can apply noticing theory to a collaborative and dynamic learning environment. To characterize students' discourse, most teachers examined how students applied chemistry content knowledge and the activity also helped teachers to attend to students' collaboration and teamwork skills and how they relate to one another during the activity (Pan et al., 2017) . The findings of the study may have implications for future research and promoting theoretical knowledge about FA and assessment knowledge through teachers' professional noticing and specifically in learning environments that promote collaboration and teamwork in problem solving.

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