Performance assessment to measure students’ explanations in chemistry learning

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Abstract. One of the components of critical thinking is an explanation. This study aims to identify critical thinking skills in aspects of explanation using a performance assessment rubric. To measure students’ scientific explanations in chemistry learning, a performance assessment rubric is needed. The arrangement of rubrics based on indicators of students’ scientific explanations on chemical equilibrium material. This research uses the RASCH analysis model, the instrument was in good category. The number of samples is 122 students from one senior high school in Surakarta, Central Java, Indonesia. The results showed students still had difficulty explaining ideas, students had difficulty explaining phenomena and connecting with relevant information.

1. Introduction
Classroom science learning needs to empower students to construct their scientific explanations. Two essential arguments are that students' conceptual understanding increases with a scientific explanation [1], [2], [3] and the need for science practice facilities to increase their understanding of scientific knowledge [2]. Critical thinking is the process of making judgments with reasons. That is an assessment that is purposeful and reflective. "Critical thinking" is "purposeful, self-regulatory assessment processes." The goal is to make logical and fair-minded judgments about what to decide or what to do. Doing self-regulation what can be done alone in identifying problems, determining problem-solving strategies, and making the best decisions [4].

Critical thinking needs knowledge, collaboration, and constructive—a more in-depth understanding of science with critical thinking. Learning in the classroom can empower students to improve their critical thinking skills. Students need continuous practical practice. In critical thinking, it is necessary to carry out self-assessment, reflection, and direction. In critical thinking practice, all skills are used together and randomly.

The components of critical thinking skills are interpreting, evaluating, explaining, analyzing, making a conclusion, and self-regulating (Faciono & Gitten, 2014). Delphi from the critical thinking process demonstrates these skills for a) evidence, b) Conceptualization, c) Methods, d) Criteria, e) Context. According to Delphi, critical thinking has a purpose, self regulation assessment that results in interpreting, analysing, evaluating, make a conclusion, and explanations of evidence, make a concept, method, critical, or make contextual considerations on which to base the assessment [4].
An explanation is of the aspect of critical thinking skills, namely compiling and justifying reasoning when making a judgment, concept, method, critical, and contextual reasoning to provide reasons and arguments [4] to solve problems and make a decision in everyday life, analysis, interpretation, or evaluation skills are needed. Critical thinking is a complex process that demands a high level of reasoning [5], [6]. Critical thinking skills require tracing sources of knowledge; the information obtained is tested for validity, test the reliability of the analysis, and describe an explanation according to the task's demands. ([7], [8]). Critical thinking builds complex knowledge, deductive and inductive reasoning, and needs creativity [9].

Critical thinking requires motivation in reasoning, not only the cognitive processes involved [10]. Dispositional, motivation, attitudes, and metacognitive are complex constructs in critical thinking [11]. It is impossible to think critically only through cognitive processes, but it also needs other aspects [12], [13]. For the construction of knowledge, critical thinking skills are needed. [14]. Based on the study results, the best critical thinking dimension is through solve the problem, practical reasoning, and make a conclusion [15].

The results showed that students with high critical thinking assessment achievements had less negative attitudes in their daily lives [16]. Many experts have assessed critical thinking skills, for example, the Watson-Glaser Critical Thinking Appraisal [17], Ennis-Weir's Critical Thinking Essay Test [18], California Critical Thinking Skills Test: College Level [19].

The idea of scientific explanation is still not achieved when students construct explanations in their way [1], [20], [2], [3] but good explanations for assessing students' concepts and reasoning [21]. Other definitions use explanation and argumentation interchangeably [22]; descriptors serve to support the connection among specific evidence and claims. Assuming that science explains natural phenomena compile evidence and construct arguments based on evidence [20]. Student competence in scientific communication can be seen from communicating explanations to others [23]. Explanations can provide a causal relationship describing what happened, based on theories of scientific ideas about how and why it happened.

Factors that influence the classroom's learning process's success include teachers, students, friends, media, assessments, and other resources [24]. The teacher's classroom role is crucial in compiling and guiding students' understanding of scientific inquiry and explanation [25] directed on how or why a phenomenon occurs [26]. An argument is a statement with justification [27]. To build scientific explanations of phenomena, confirm claims, use evidence, and sound scientific fundamental, it is indispensable for students to provide explanations and arguments [28]. A fundamental aspect of scientific investigation is involving students in compiling to explain and construct arguments [29]. The main purpose of science education is to help students find evidence and reasons for ideas or knowledge claims that we attract in science [30].

Students recognize science as a collection of static facts, but science is a social process in which knowledge is built [31]. There is a connection between students' knowledge of building science and argument Students need to be involved in building a deeper understanding of the knowledge content [31]. Students in the argumentation skills group through dilemmas on human genetics studied higher levels of biological content than a group who studied genetics by traditionally [32].

Learning objectives are important for students in empowering scientific explanation skills, students often have difficulty explaining and preserve their claims [33]. It is not easy for claims and evidence to be linked by both children and adults. It is not easy for children in the class, even though there is a prominent scientific explanation [27]. It is not easy for students to find relevant evidence [34] and appropriate to their claims [35].

Children and adults' ability to built arguments and found that this practice often does not come naturally [27]. They are still having a hard time making harmonize between claim and evidence. Students still have Students still have a hard time using proper evidence [34] and gather sufficient evidence for their claim [35]. It is not easy for students to make decisions and provide good reasons for choosing evidence to support their claims [31]. Students having trouble justifying why their evidence supports their claims [22]. Teacher influences the success of the classroom's learning process.
in developing student explanations based on evidence [36]. Arguments cannot be mastered by students naturally; it needs to be taught. The role of the teacher influences the success of the learning process teacher's role findings of arguments differs from what is considered arguments. The learning process can support, naturally, scientific explanations, for example, by asking questions and conducting experiments [38].

The learning process introduces scientific explanations to students, namely understanding scientific explanations, reasons, modeling, and everyday life [39]. Teachers need to understand scientific explanation and its three components: claims, evidence, and reasons [40]. Students are helped improve their understanding by showing how to use evidence, claims, and reasons [41]. The teacher can exemplify good arguments through strong and weak arguments, both oral and written [37].

Teachers can construct student explanations by engaging students in discourses that are different from everyday life and in the classroom. The development of scientific explanations or claims in science that is different from everyday life is needed by students [42]. In the classroom learning process, students need to understand the reasons behind scientific explanations and why do they provide evidence and reasons to support their claims to obtain a potent understanding and construction of scientific explanation [43].

Students are invited to practice in the teacher's learning process about modeling scientific explanations, make a reason for explicit scientific explanations, defining scientific explanations, and associate scientific explanations with daily explanations. It is known that teachers' use of learning practices can affect students' constructions in scientific explanation [28].

The main characteristic of scientific explanation is adopting the causal model [44], the causes that form the basis of the phenomenon, and the unification model [45], namely the broad explanation of the big scientific ideas used to understand natural phenomena. Scientific explanations in science education provide information or descriptions requested, clarify specific points of view, or ideas, justify actions or beliefs, support claims, or provide a sequence of causes for an event [46], [47].

Scientific explanations have a systematic, detailed, and accurate character [48], and new phenomena are explained by new theories and scientific facts [3]. Knowledge of nature can be enhanced by scientific explanations (Strevens 2008), what natural phenomena occur, how they arise, and why they persist [2]. This character makes science explanation central to science practice and science education [1]. Experts have developed theories and models of scientific explanation, and significant contributions have been made to augment discussions about their structure, as well as the strengths and weaknesses of their propositions [48]. The explanation model is the causal explanation and the unification model. The causal explanation model studies on the nature of explanation, emphasizing the importance of identifying underlying causes outside of phenomena to understand how and why certain phenomena behave as such [44]. The unification model relies on science's ideas to provide an integrated framework for understanding related phenomena [45]. The causal explanation model is popular in science and the scientific philosophical community with the argument that causality is an important part of natural phenomena. [44].

Those models can be used together: the unifying model provides the theoretical basis for explanation. The order of information is given to the causal explanation of phenomena coherently and progressively. The unification model searches to clarify natural phenomena with a few scientific ideas. The purpose of science education is to provide students with big science ideas that can be used to understand the essence of various phenomena that applies globally, not only in the region [1].

This view is well received in science education reform, recognizing that big ideas have the power to explain the objects, events, and phenomena that students encounter in life during and after the school year [49]. Furthermore, they can be used to develop new scientific explanations. Second, when embroiled in identifying causal explanations for a phenomenon, students are encouraged to deduce the underlying causes and find structural relationships of the world's phenomena. Students develop deeper understanding of natural phenomena than superficial generalizations from observation [51]. The explanation involves constructing a causal story that understands a phenomenon by explaining what happened and use scientific ideas to formulate theories about how and why it happened [1].
In preparing of scientific explanations, students need to create a conceptual framework for observing phenomena, seek relevant information, infer the unobservable world, understand the underlying causes, and establish logical relationships among these causes. Besides, students need to deepen and use the big ideas of science to understand how and why certain phenomena occur. The dimensions of a good scientific explanation are connection, conceptual framework, causality, and compatible level of representation. Students still struggle with all dimensions [51], [52].

2. Research Method
The research method used is descriptive quantitative. Data collection was carried out using a performance assessment rubric on chemical equilibrium material. The performance assessment rubric is represented as a question about chemical equilibrium. The RASCH method was used to analyze data [53]. A total of 122 students from a high school in Surakarta, Central Java, Indonesia, were selected.

3. Results and Discussion
Explanation activities are critical to ensure that what students understand is following what scientists should do when looking for solutions to problems. In this regard, it is necessary to make an instrument that can measure students' ability to provide valid and reliable scientific explanations.

The instrument rubric to measure the ability to explain was generated from a qualitative analysis of high school students' scientific abilities to explain chemical concepts' problems according to critical thinking skills indicators. The rubric performance assessment of students’ explanations can be seen in Table 1.

Table 1. Students’ explanation indicators in chemistry learning

| Operational definition | Aspect | Indicator | Score |
|------------------------|--------|-----------|-------|
| Explaining is presenting convincingly and coherent way (relationship) results | Ideas | 1. Build ideas | 1 = If 1 indicator appears |
| | | 2. Collecting phenomena | 2 = If 2 indicators appear |
| | | 3. Describe the phenomenon | 3 = if 3 indicators appear |
| | | 4. Relating phenomena with prior knowledge | 4 = if 4 indicators appear |
| | Evidence | 1. collect evidence | |
| | | 2. Provide a statement (claim) based on evidence | |
| | | 3. compile arguments (reasons) using relevant data and theories | |
| | | 4. shows the flow of logic and reasoning | |
| | Information | 1. Presenting facts | |
| | | 2. Gather relevant information | |
| | | 3. Link initial knowledge with the information gathered | |
| | | 4. Presenting the results of reasoning in the form of convincing arguments | |
| | Solving problem | 1. Identify the problem | |
| | | 2. Develop alternative solutions to problems | |
| | | 3. Explain data, facts that support problem solving | |
| Operational definition | Aspect | Indicator | Score |
|------------------------|--------|----------|-------|
|                        |        | 4. Describe a logical flow of problem solving |

### Conclusion

1. Concluding based on data
2. Concluding based on evidence
3. Concluding based on relevant information
4. Summing up with logical reasoning

The analysis of the validity of the questions resulted in the form of construct validity and content validity. The results of the analysis carried out with the Rasch model, research findings on the item dimensionality output tables; the analysis results in Table 2.

**Table 2. Results of the analysis of the validity level of the item suitability**

| ENTRY | TOTAL | TOTAL | MODEL | INFIT | OUTFIT | PTMEASUR−AL | EXACT MATCH |
|-------|-------|-------|-------|-------|--------|-------------|--------------|
| NUMBER | SCORE | COUNT | MEASURE | S.E. | MNSQ | ZSTD | MNSQ | ZSTD | CORR. | EXP. | OBS% | EXP% | Item |
| 10 | 329 | 122 | .75 | .14 | .76 | 2.28 | .69 | -2.65 | .64 | .62 | 63.1 | 54.0 | R5 |
| 6 | 339 | 122 | .56 | .14 | 1.15 | 1.30 | 1.10 | .80 | .56 | .63 | 46.7 | 52.6 | R1 |
| 8 | 351 | 122 | .34 | .14 | 1.09 | .75 | 1.10 | .79 | .48 | .64 | 50.8 | 52.2 | R3 |
| 1 | 355 | 122 | .26 | .14 | 1.06 | .57 | 1.11 | .88 | .70 | .65 | 58.2 | 53.2 | Q1 |
| 2 | 357 | 122 | .23 | .14 | .94 | -.47 | .95 | -.36 | .59 | .65 | 59.8 | 53.2 | Q2 |
| 5 | 360 | 122 | .17 | .14 | 1.05 | .47 | 1.02 | .22 | .63 | .65 | 54.1 | 51.9 | Q5 |
| 9 | 361 | 122 | .15 | .14 | 1.11 | .91 | 1.14 | 1.06 | .50 | .65 | 46.7 | 51.9 | R4 |
| 12 | 364 | 122 | .09 | .14 | 1.03 | .25 | .92 | -.55 | .68 | .66 | 54.1 | 53.0 | S2 |
| 7 | 371 | 122 | -.05 | .14 | 1.08 | .71 | 1.20 | 1.45 | .66 | .66 | 45.9 | 55.4 | R2 |
| 13 | 373 | 122 | -.09 | .14 | .77 | -1.97 | .73 | -2.19 | .74 | .66 | 63.1 | 55.5 | S3 |
| 3 | 378 | 122 | -.19 | .14 | 1.16 | 1.24 | 1.23 | 1.58 | .58 | .67 | 55.7 | 55.5 | Q3 |
| 15 | 387 | 122 | -.38 | .15 | .71 | -2.51 | .70 | -2.33 | .85 | .67 | 74.6 | 59.1 | S5 |

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Table 2 describes the analysis of the validity level of the items' suitability, namely from 15 items, 14 items were declared fit, and 1 item was not fit because they did not meet the MNSQ Outfit and ZSTD Outfit standard, namely questions with the S1 code. If the questions have been declared fit, they meet the criteria and guarantee that students' level of understanding is tested through appropriate and quality items. The reliability analysis of the items result in Table 3.

**Table 3. Student reliability values and item questions**

| TOTAL SCORE | COUNT | MEASURE | S.E. | MNSQ | ZSTD | MNSQ | ZSTD |
|-------------|-------|---------|------|------|------|------|------|
| MEAN        | 45.2  | 15.0    | 2.59 | .41  | 1.01 | .08  | 1.00 | .10  |
| SEM         | .8    | .0      | .11  | .00  | .04  | .13  | .04  | .12  |
| P.SD        | 8.4   | .0      | 1.25 | .05  | .45  | 1.41 | .46  | 1.35 |
| S.SD        | 8.4   | .0      | 1.25 | .05  | .45  | 1.41 | .46  | 1.35 |
| MAX.        | 57.0  | 15.0    | 4.68 | .60  | 2.21 | 3.38 | 2.29 | 3.12 |
| MIN.        | 27.0  | 15.0    | -.54 | .35  | .19  | -.61 | .19  | -.40 |

| REAL RMSE   | .45   | TRUE SD | 1.16 | SEPARATION | 2.56 | Person RELIABILITY | .87 |
| MODEL RMSE  | .42   | TRUE SD | 1.18 | SEPARATION | 2.84 | Person RELIABILITY | .89 |
| S.E. OF Person MEAN = .11 |

Person RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .91 SEM = 2.56

**SUMMARY OF 15 MEASURED Item**

| TOTAL SCORE | COUNT | MEASURE | S.E. | MNSQ | ZSTD | MNSQ | ZSTD |
|-------------|-------|---------|------|------|------|------|------|
| MEAN        | 367.8 | 122.0   | .00  | .14  | 1.00 | -.10 | 1.00 | -.12 |
| SEM         | 5.5   | .0      | .11  | .00  | .07  | .49  | .07  | .46  |
| P.SD        | 20.7  | .0      | .42  | .01  | .24  | 1.81 | .26  | 1.73 |
| S.SD        | 21.4  | .0      | .43  | .01  | .25  | 1.88 | .27  | 1.79 |
Table 3 describes the student's reliability value, which is 0.89, which means that the student's reliability is good because the value is 0.8-0.9. Likewise, the questions' reliability value obtained a value of 0.89, which means that the items' reliability was good, namely, 0.8-0.9. While the Cronbach alpha value is 0.91, the reliability value between students and the questionnaire items is outstanding. The assessment is based on the Cronbach alpha value, which can measure the interaction between the person and the items as a whole—determined on the value of separation and alpha Cronbach value.

The measured column shows the item's logit; the more significant the logit, the higher the item difficulty. Table 4 shows that the most challenging questions are questions with code R5, while the most straightforward questions for students to do are questions with code S1.

The results of the analysis of the validity of the questions resulted in the form of construct validity and content validity. The results of the analysis carried out with the Rasch model obtained results on the item dimensionality output tables, the results of the analysis of the validity level of the item suitability shows that from 15 items, 14 items were declared fit and 1 item was not fit because they did not meet the MNSQ Outfit and ZSTD Outfit criteria, namely questions with the S1 code. If the questions have been declared fit, it means that they meet the criteria and can guarantee that the level of understanding of students is indeed tested through appropriate and quality items.
Table 5. Validity and reliability value item and person

| Variable | Separation | Reliability | \( \alpha \) Cronbach |
|----------|------------|-------------|-----------------------|
| Students | 2.84       | 0.89        | 0.91                  |
| Item     | 2.78       | 0.89        |                       |

Table 5 shows the results of the student's reliability value, which is 0.89, which means that the student's reliability is good because the value is 0.8-0.9. Likewise, the reliability value of the questions obtained a value of 0.89, which means that the reliability of the items was good, namely 0.8-0.9. While the Cronbach alpha value is 0.91 which means that the reliability value between students and the questionnaire items are categorized as special. The assessment is based on the Cronbach alpha value which can measure the interaction between the person and the items as a whole. Determined on the value of separation and alpha cronbach value.

How to evaluate data for students, they need many chances to assess rich and complex data models [54]. We believe students also need many chances to join in scientific explanation. After focus lessons, students build about ten scientific explanations in the the classroom. Students gather data of investigations and their scientific explanations on the student investigation sheet, namely provide written scaffolds to support the construction of their description. This written scaffolding provides context-specific and general support and fades, or provides less detail, over time.

Student descriptions are inappropriate or given at a poor level of detail [55]. Students are difficult to identify which key aspects are relevant and which should be highlighted [52]. It is not easy for students to recognize relevant information, but good explanations provide relevant information. Students often focus their attention on detail, have difficulty reducing seemingly unrelated events to one global idea, and determining the clarity of phenomena [56]. Students often have difficulty presenting a causal story in which events occur as a result of the interaction between various components [51].

Students' explanations are often less logical and consistent. Students reduce complex information, unknown contexts, focus on limited decisions and ignore other relevant reasons. As a result students tend to simplify their reasoning, a simple linear causal sequence in which each cause is a cause from another entered cause, and where effects are only felt in one direction [51].

4. Conclusion
This study aims to determine students' critical thinking skills in the aspect of explanation. Students' explanation skills are measured by performance assessment rubric. Indicators of aspects of critical thinking skills of explanation consist of five indicators, namely explanation based on ideas, explanation based on evidence, explanation based on information, explanation based on problem solving and explanation based on conclusions. The results showed students still had difficulty explaining ideas, students had difficulty explaining phenomena and connecting with relevant information. The performance assessment rubric for measure students' explanation was analyzed using the RASCH model which showed that the instrument was in good category.

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