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Developing a context-based assessment: Task characteristic facet

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Developing a context-based assessment: Task characteristic facet

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Abstract. The context-based learning (CBL) approach has been recommended by many chemistry educators to improve students' engagement in the learning chemistry and the perceived chemistry relevance. The use of the context enables the student to apply the content knowledge and see the relevance of chemistry for many aspects of life. CBL is continually discussed by many experts around the world through various studies. The aim is CBL approach may perform better. The design of the context-based assessment affects the success of CBL. The current study highlights on the facet of task characteristics as a critical aspect in the processes of designing context-based assessment through chemistry text. Understanding the task characteristic facet may help the teacher to develop meaningful assessments for students, which may promote various skills in studying chemistry, such as HOTS and multiple representations skills.
Keywords: *context-based, chemical literacy, assessment*

1. Intoduction

Bringing the science, technology, and environmental issues into chemistry learning through context is a benefit to open students' thinking and understanding that chemistry has a contribution to those issues. Besides, the use of context will make the chemistry classroom to be more meaningful for students [1], [3]. The context may assist students in establishing the meaning of chemistry learning (about why they need to learn the required materials); helping them to relate the learning materials to their aspect of lives (acknowledge the contribution of chemistry), and being able to construct coherent mental maps of subject (see the interconnected content knowledge) [4]. Emphasizing content knowledge in learning chemistry without attaching the origin scientific context make the students assume that chemistry is sets of isolated facts, and may deform the nature of chemistry as a scientific knowledge [5]. Furthermore, the acquisition of a largish number of isolated facts disables the students make the meaning about what they learned and lead them to have low engagement in the learning and forgetting the material they have learned [4]. The student who has a good constructed mental maps, and a broader perspective in seeing the relation between content and the context, can acknowledge every part of chemistry that has significant contribution for human's lives, earth life or biosphere, through natural phenomena, (e.g., carbon and nitrogen cycle, corrosion) or applied technology products (e.g., lithium battery, artificial photosynthesis). Of course, the contribution has two impacts, advantages (e.g., medicines, hydrogen fuel cell) or damages (e.g., contaminated water or gas pollution caused by industries). Therefore, the student will worth that chemistry is important for being learned for today and for the future towards global ecological sustainability. Besides, understanding chemistry

through context may lead students to develop their capacity as responsible decision-makers in using science and technology for daily lives [6], [8]. The chemistry discipline ought to shape students' responsibility and awareness of these global issues [9], [10]. For all these reasons, context-based assessment has to be designed to enable student to transfer their content knowledge understanding into context in meaningful ways (tie up the students' pre-knowledge, motivation, and ideas).

Context-based assessment is part of the context-based learning (CBL) approach that uses context to develop students' scientific ideas. The CBL approach is projected to overcome five challenges facing chemistry education, these are overloads of content knowledge, isolated facts, low relevance, low of transfer, and inadequate emphasis on inculcating scientific literacy for the student who does not continue study the subject [4]. Regarding these challenges, six CBL approaches are initiated and implemented in five different countries and education systems: Chemistry in the Community and Chemistry in Context in America; Salters Advanced Chemistry in England; Industrial Chemistry in Israel; Chemie im Kontext in Germany; and Chemistry in Practice in the Netherlands [11], [16]. Fostering and hindering factors during the developmental implementation of the CBL approach has been suggested based on the analysis of five CBL approaches (Chemistry in the Community does not include) with respect to addressing the five challenges of chemistry curriculum, which summarized in three categories: (a) the nature of the design and developmental process, including the cyclic nature of the design and developmental process, the influence of the attitude of teachers as a key factor for success or failure of the innovation and the use of the collected data in the cyclic developmental process; (b) key characteristics of the course-design framework, including the quality of the frameworks for context-based chemistry education and the robustness of the design in the formal curriculum; (c) conditional circumstances during the development, including the assessment of learning results, requirements from stakeholders in further education and the quality of the team of developers within a systemic organisation. Hence, the success of the CBL approach heavily relies on the quality of curriculum materials and the implementation in the classroom, including the design of context-based assessment. Analysis of task criteria and problems-solving processes are critical aspects in designing suitable assessment and adequate tasks and analyzing students' responses [17].

We developed context-based assessment through chemistry texts which have been used for research to measure high school students' chemical literacy as a result of an experimental course of the CBL approach following the four-phases "Chemie im Kontext" [14]. During the development, we identified important features that are critical to account in the process of designing context-based assessment through chemistry text. This paper will zoom in facet of task characteristics and present a sample of context-based items and the result of context-based item test.

2. Theoretical background

The development of context-based assessment (chemistry text) is obviously dissimilar with the development of non-context-based assessment (conventional). It is due to the presence of context, that connects the content knowledge into the real world phenomena or problems to make the assessment more relevant and authentic. Figure 1 presents the features to construct the context-based chemistry text both theoretical and practical based on our study (see Figure 1).
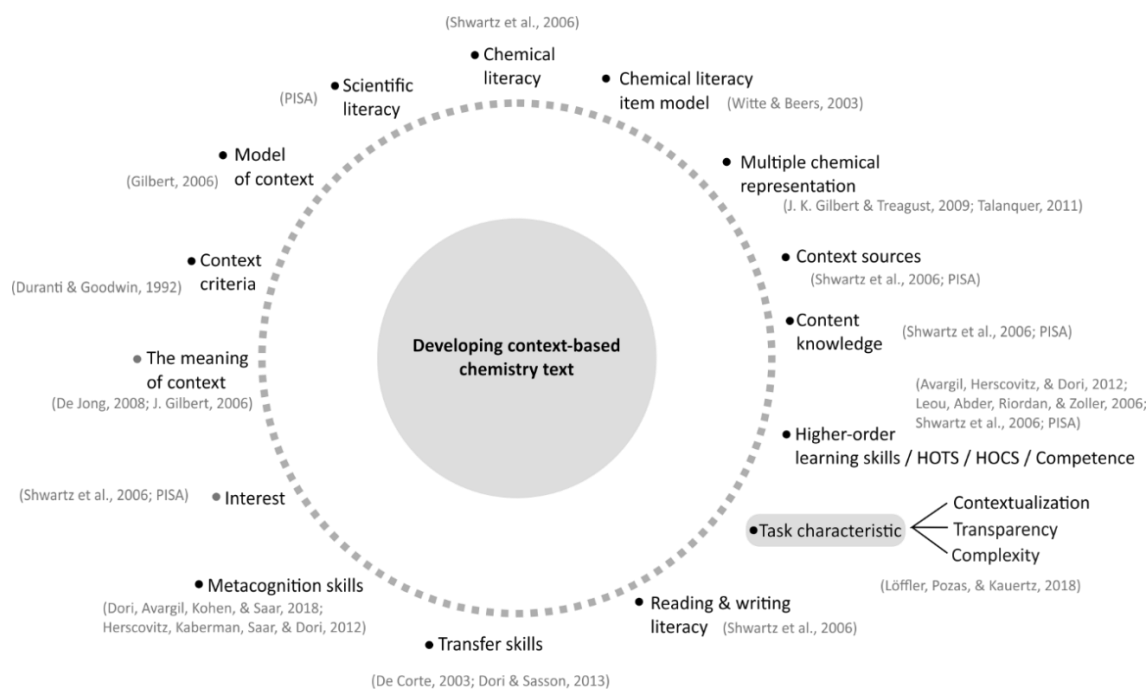
Figure 1. Features in the development of context-based chemistry text.

The facet of task characteristics might be derived from the theoretical framework of the context model [18]. It consists of three task characteristics: contextualization, which relates to given amount of information adjunct to the relevant real object (and its characteristics) and events described in the problem situation (surface structure level); complexity, which relates to the structure of the problem solution (deep structure level); and transparency, which relates to features that connect the surface and deep structure (see figure 2). All three task characteristics can be modified in two levels, (e.g., low and high). With this model of context, it is possible to undersee the effects of these three task characteristics on the process of solving context-based problems. Applying the task characteristic into context-based assessment is varied and depends on the types of item model (e.g., cased-based problem, news-paper stories, comics, short articles, etc.). Since the context is a set of information, the ability to identify information on the level of the surface, deep and link both them is a critical manner in solving the problems.
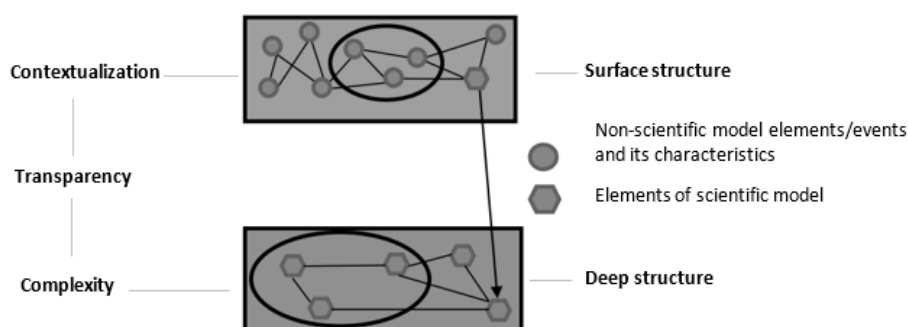
Figure 2. The theoretical framework of the context model.

2.1. Sample of context-based items

The following is a sample of context-based items which is developed for vocational high school student, specifically in Analytical Chemistry program on the topic of physics constant, colloids, and chemical bonding. The sample of context explores how content knowledge of matter properties and

classification of the matter is presented with the discussion of the separation method of Cajuput oil from Kayu Putih Tree.

Figure 3. Sample context-based chemistry probles.

Kayu Putih (Melaleuca leucadendron) is a familiar plant in Indonesia because it can produce Cajuput oil, that has medicinal properties, insecticide, and fragrance. Besides, Kayu Putih trees used for the conservation of degraded land and the woods are used for various purposes. For that reason, Kayu Putih trees are conservated because high economic and environmental benefit.

Cajuput oil is obtained from the distillation of Kayu Putih leaves. Cajuput oil contains cineol ($C_{10}H_{18}O$). The greater the amount of cineol, the higher the quality of Cajuput oil. Besides, Kayu Putih leaves also contain other components, such as benzaldehyde, limonene, and pinene. The process of extraction Cajuput oil from the leaves are conducted with the evaporation of oil from the leaves that are boiled together with water and then the vapor, are condensed. Last, the Cajuput oil in the condensed liquid is separated physically and needs to be saved properly since volatile.

Questions:

- Identify and explain the mixture (heterogeneous, colloid) and compound in the process of extraction Cajuput oil.
- What are the matter properties that applied to obtain Cajuput oil from the beginning till end of extraction process? Give explanations.
- Why on a hot day, people who are close to *Kayu Putih* trees will be able to smell the perfume from a considerable distance (far)? Compare with the water molecule to explain the properties of *Kayu Putih* essential oil.
- Are there any chemical reaction changes during the process of extraction Cajuput oil? Please give an explanation.

To get the answer, the student needs to understand the text, mainly in chemical information. Interpreting, and analyzing the meaning of words, sentences are needed to make connection between content knowledge, questions, and problem-solving. Contextualization relates to how the context delivers the problem situation or contextual information that should be translated into the chemistry model, which may be high or low level. The following is a sample of low contextualization (excerpt of the paragraph)

The process of extraction Cajuput oil is done by the evaporation of oil from the leaves that boiled together with water and then, condensed. The oil and water will boil and mixed together in the form of vapor, then cooled to make the state of oil and water becomes liquid. Since the liquid of water and oil has different density properties, the oil of the Cajuput oil can be separated physically.

Then, the task complexity relates to the elaboration of the problem solutions. From the sample context-based items, question number 3 asks what the factor that makes the aromatic sweet of Kayu Putih smelled by people around even though the distance is far. The answer is that Cajuput oil is a volatile substance as stated in the last sentence. With a high temperature of the weather, the Cajuput oil vaporized and spread to the air. Then, the task asks to compare the volatile properties of Cajuput oil with non-volatile water. The question can be answered by comparing the molecule structure of $C_{10}H_{18}O$ with H_2O. Student needs to explain the intermolecular force between molecules, specifically in hydrogen bond formation between two substances, cineol, and water.

The last task characteristic is transparency. While contextualization and complexity are clearly hierarchically measurable, transparency needs more consideration in order to be measured hierarchically [18]. Since the function transparency is connecting the contextualization (surface

structure level) and complexity (deep structure level), the modification of high or low transparency may come from the modified questions or problems to the provided information, e.g. question (c) has higher transparency compared with the question: why Cajuput oil is volatile compared to water molecule?

3. Research method

The study describes how students apply their content knowledge in solving context-based problems (chemistry text). Sixty high senior school students from the natural science program (grade 12th) were tested after exposed by the CBL approach of "Chemie im Kontext" for 3 weeks (2 meetings per week). The topic of learning is about redox and electrochemistry. The context-based chemistry text has been validated by two chemistry faculty members, who expertize on electrochemistry and inorganic chemistry. Also, it has been pilot tested with the item reliability measured at 0.83. The following table is the description of electrolysis learning phases.

**Table 1.** Phases of "electrolysis" CBL approach.

Phases	Description	Aim	Task questions
Contact	Introduce context using Lead-acid electric accumulator	Engage students' interest & show the relevance of chemistry in daily lives, stimulate reasoning	Why Lead-acid electric accumulator can be recharged after the loss of power of the electricity?
Curiosity and planning	Direct students to be curious about the topic, identify and develop important questions	Identify and develop an important question for the student to learn what concepts required and why they required it	What happens to the electricity which flows into the accumulator when recharged?
Elaboration	Developing the basic concept of the electrolysis through inquiry activities in the worksheet and team collaboration task	Develop basic concept through several students' tasks: do the worksheet, answer questions, discussion, searching information, & presentation	How redox relates to electricity? What happens to chemicals inside during the process of recharge?
Deepening and connecting	Applying the concept into a new context which demands higher problem solving	Deepen the understanding, connect and apply the concept into a new context	How the Chromium electroplating of car felloes follow the concept of electrolysis?

4. Results and Discussion

We analyze the students' written responses by the correctness criteria for each question: fully correct, partially correct and incorrect answer. The following table is the item set and the result of students' tests on the topic of electrolysis titled "Copper electrorefining". The type of context-based chemistry text for the test is exposition text, which consists of seven chemical problems.

Table 2. Item set of copper electrorefining and students' distribution response.

Context	Content knowledge	Task	Type of knowledge	Item	% fully correct	% partially correct	% incor rect
Copper Electror efining	electrolysis component	Drawing the simulation of Cu electrorefining	conceptual, procedural	3a	20	13	67
	redox equations	Writing the redox equation of Cu in the anode	conceptual, procedural	3b	13	22	65
		Writing the redox equation of Cu in the cathode	conceptual, procedural	3c	7	21	72
	redox result	Explaining what happened to the mass of Cu plate in the anode	conceptual	3d	13	15	72
	redox equations	Reasoning what happened to impurities metal of Ag	conceptual, procedural	3e	5	5	90
		Reasoning what happened to impurities metal of Zn	conceptual, procedural	3f	3	7	90
	Faraday law	Calculating the mass of electrolyzed Cu in the cathode	procedural	3g	22	13	65

(a) (b)
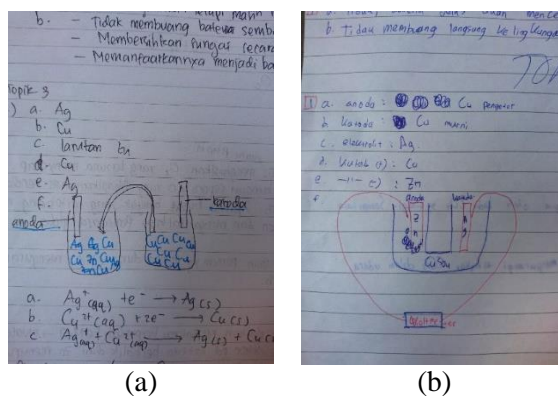
Figure 4. Sample of students, respons in drawing the simulation of Cu electrorefining.

The context of Cu electrorefining exposes the process of electrolysis of Cu plate, which still contains impurities metal, Ag and Zn. The impurities metal needs to be removed to get a high purified Cu plate, so the electrolysis method is conducted. The high purified Cu plate plays as one of the two required electrodes. The process of electrorefining follows the principle of electrolysis. Students' task is to identify the component of electrorefining, drawing the simulation, and explain all associated redox reactions based on the context of Copper electrorefining. The context highlights on contextualization of the problem situation. The items are correlated one to others, hence, comprehensive understanding of the context is required besides the conceptual understanding about electrolysis.

Written students' response analyses indicated that 67 % of the student was unable to draw the simulation of electrorefining, whereas only 20 % was correct in visualizing the simulation (see table 2). To draw the simulation, the student requires to identify all the components of electrolysis: a cathode; anode; electrolyte; positive and negative terminal. It was not a simple case since this chemical information was implicitly stated in the context. They needed to translate the contextual information in chemistry text into the chemistry model based on their understanding of the electrolysis concept. Figure 4 presents samples about how the student draws the simulation. Both of them were wrong in selecting the anode and the cathode. Picture *a* was likely voltaic cell. The students drew the vessel separately with a salt bridge connects them. While picture *b* shows a voltmeter connect the two electrodes in the "U" tube. The student was likely doubtful to draw the electrolysis separately or together. This result shows that the student has misinterpretation, misconception, and insufficient conceptual understanding to solve the context-based chemical problems.

Failing to identify the anode and the cathode will make the student are wrong in answering item 3b and 3c. The result showed that 67 % of the student was not able to solve item 3b and 72 % for item 3c. Both item 3b and 3c are correlated conceptually, thus the difference percentage 13 % with 7 % pointed out that few students select the wrong electrode. They chose impurities metal as the electrode. Next item, 3d, examined how student connects the concept of Cu oxidation in macroscopic level. The mass of Cu at the anode will decrease during the electrolysis due to the Copper metals dissolve into ions. The ions migrated to different Cu plates. This correct explanation was only noticed by 13 % of students in a fully correct response and 15 % in the partially correct response. Most students left the problem and skip to the next item, which they thought may be easier.

Item 3e and 3f demand the student to analyze what happened to impurities when it electrolyzed. The student was expected to use scientific reasoning based on electrochemical properties (standard reduction potential) and prove the calculation. The results showed that only 5 % of students give the correct answer at item 3e and 3 % at item 3f. They argued that Ag not electrolyzed because the given electricity potential 0.34 V was not enough to reduce solid Ag. Meanwhile, Zn would oxidize because its standard reduction potential was more negative. The answers were still correct, but they could not provide empirical calculations to claim their reason. To claim the reason, students needed to more elaborate their answer based on the cell potential calculation. Next, 5 % of the student was partially correct at item 3e and 7 % at item 3f. They only stated that Ag metal would still exist, while Zn metal would oxidize. No argument explained. Probably, the student didn't know to express the reason. The rest of the students left the problem, and few of them answered that the Ag metal reduced. These results showed that the items were too difficult for the student. To answer the item is the same as when students determine cathode and anode between two different metals. Student requires to calculate its cell potential to check whether the reaction occurs spontaneously or not. In the task, the student requires to reflect on what chemical reaction in the anode and the cathode. They need to realize that Cu metal will oxidize firstly into ion form, Cu^{2+}. When Cu^{2+} reduced into solid Cu in the cathode, the ions also react with impurities (solid Ag and Zn). Student needs to calculate their cell potential to determine whether Ag or Zn which will oxidize.

The last item, 3g asks the student to show procedural knowledge of calculating the mass of the product from electrolysis. Results showed that 22 % of students were success give a complete answer with the right formula and calculation, while 13% did not give a complete answer, they forgot to write a unit of mass. Meanwhile, 50 % of the student was unable to calculate the result. They were miscalculated and left the problems. Most typical students' mistake was not careful to convert the current (100 mA) into Ampere unit and did not complete the calculation until the last solution.

Based on the analyses of students' response, the deficiencies in solving the context-based problem was probably caused by the difficulty in making the structural meaning between the context and content knowledge. Particularly, on the use and understanding of the chemical multiple representations. The context provided explicitly enough chemical information about the process of electrorefining, but the students were not able to translate it into the chemistry model by concept transfer and analogical thinking [19]. They were difficult to translate the information in the text into

chemical symbolic. This happened because the students are lack experience with the macro type level of chemical representation [20]. In school, chemistry learning is more emphasizes the use of a symbolic level rather than the macro and sub-micro. The origin scientific context sometimes is ignored and not provided by the teacher. For instance, when discuss the electrolysis of melted NaCl salt and NaCl solution, the explanation for different product of oxidation reaction in cathode: $Na^+_{(aq)} + e^-$ $\rightarrow Na_{(s)}$ and $2H_2O_{(s)} + 2e^- \rightarrow H_{2(g)} + 2OH^-$ often head directly into rote memorization of symbolic level rather than choose to provide explanation based on the scientific reasoning. The learning does not support and give chances for the student to think scientifically for the answer. The answer or the explanation does not start from the basic properties of salt and solution, the existence of solvent (H_2O), and the electrochemical properties. This is probably might the reason why electrolysis (redox) becomes difficult topic among students in senior high schools since it has lots of rote memorization of the symbolic level.

The contextualized task of electrolysis through problems situation and questions are able to promote students' scientific literacy and Higher Ordered Thinking Skills (HOTS), particularly on the concept development and concept transfer of electrolysis in the new context. In a complex situation encountered, student requires to extract the potential chemical information from the context; understanding the new situation; recognizing what content knowledge and skills are required; transforming them to fit the new situation; and integrating them with knowledge and skills in order to think, act, and find problem-solving in the new situation [21]. This process involves lots of high thinking skills compared to conventional assessment, which most of them demand lower ordered thinking skills (e.g. rote memorizing and applying repetitive algebraic calculation). With the higher cognitive demand, the context-based assessment may encourage the student to think critically and applying general skills, such as problem-solving strategies [22]. The high-quality tasks may engage deep cognitive processing and self-regulated construction of meaning that necessary for conceptual understanding [23]. By higher contextualized tasks, it may facilitate the student to have meaningful learning since it involves a high level of abstraction, generality, and inclusiveness [24].

5. Conclusion

Based on the result of the students' test, the facet of task characteristics may influence students' performance in solving the context-based problems. The founded difficulties, misconceptions, and concept transfer inability in students' responses might be caused by the complex problem situation encountered by students that demand higher cognitive skills. By understanding the facet of task characteristics, may help the teacher in designing meaningful context-based assessment, which may assess students' HOTS and practice scientific literacy, particularly on chemical literacy.

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