



## Development of Four-Tier Instrument at First Intermediate Level Chemistry Concepts

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**Abstract:**

Chemical concepts are tiered from simple to complex. If misconceptions occur in simple concepts, they can cause misconceptions in complex concepts. The four-tier instrument is a tool for detecting misconceptions. This research aims to develop and describe the validity and reliability of a four-tier instrument on junior secondary-level chemistry concepts. This development research consists of 6 procedures: (1) concept mapping, (2) testing, (3) defining unscientific concepts, (4) developing four-tier instrument prototypes, (5) validating four-tier instrument prototypes, and (6) finalization of four-tier instruments. The developed four-tier instrument consists of 27 questions that measure chemistry concepts at the junior intermediate level. The instrument received an expert validation score of 92.81% with very valid criteria. The test results on 30 samples showed a reliability value based on a Cronbach alpha score of 0.713 with good criteria. The four-tier instrument on lower secondary level chemistry concepts meets the validity and reliability requirements so that it can be used to diagnose misconceptions on lower secondary level chemistry concepts.

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### Introduction

Chemistry is a subject studied by students at the senior secondary education level (SMA/MA). The facts show that several topics from chemistry appear in science subjects in junior high schools (SMP/MTs). This topic is matter and its changes, which are contained in KD 3.3 class VII and material particles (atoms, ions, molecules) KD 3.8 class IX. Thus, students at the junior high school level must study chemistry. Material particles (atoms, ions, molecules) that must be studied at the junior secondary level are topics that contain abstract and microscopic concepts ([Mursiti, et al, 2006](#)). These abstract characteristics can trigger students' difficulties in learning them. [Taber \(2001\)](#) and [Erduran & Scerri \(2002\)](#) reported that many students had difficulty understanding atomic structure.

Students' difficulties in understanding concepts can trigger them to interpret them themselves. When students' understanding differs from the scientific community's understanding of a concept and occurs consistently, it is called misconception ([Fantiani et al., 2023](#); [Karim et al., 2022](#); [Yolviansyah et al., 2022](#)). Misconceptions in chemistry learning are fatal ([Savira, et al, 2019](#)). Chemical concepts are tiered, starting from simple ones to concepts at a higher level ([Astutik, 2017](#)). Thus, if students experience misconceptions about simple concepts, it can be assumed that they also experience misconceptions about higher concepts. It is supported by research by [Jusniar, et al \(2020\)](#) which reports that misconceptions about reaction rates influence the occurrence of misconceptions about chemical equilibrium. Reaction rates are a prerequisite for studying chemical equilibrium. Therefore, misconceptions that students may experience must be identified as early as possible to avoid forming a chain of misconceptions.

[Anwarudin et al. \(2019\)](#) stated that diagnostic tests could be used as an alternative to identify misconceptions. This is supported by the opinion of [Treagust & Tsui \(2010\)](#), who state that diagnostic tests are a good method for identifying misconceptions. One form of diagnostic test is a four-tier multiple choice. The four-tier form consists of tier-1, which contains questions; tier-2, which contains the level of confidence in the answers in tier-1 tier-3, which contains reasons related to the answer choices in tier-1; and tier-4, contains the level of confidence in the reasons at tier-3 ([Gurel et al., 2015](#)). Apart from diagnosing misconceptions experienced by students, the four-tier diagnostic test is also effective in identifying students' conceptual understanding ([Irawati & Sofianto, 2019](#); [Fakhriyah & Masfuah, 2021](#)). Based on the four-tier diagnostic test results, students can differentiate their' concept understanding into levels of understanding the concept, partially understanding the concept, and not understanding the concept ([Gurel et al., 2017](#); [Rohmah et al., 2022](#)).

Several research report that there have been misconceptions about science subjects in junior high schools ([Anggraeni, et al, 2018](#); [Putri & Subekti, 2021](#)). Based on these facts, it is necessary to know whether the misconceptions that occur in chemistry concepts in junior high school are related to each other. Therefore, research was conducted to develop a four-tier instrument for junior high-level chemistry concepts.

## Research Method

This development research adopts the four-tier instrument development procedure carried out by Habidin & Page (2019), which consists of the steps (1) concept mapping, (2) testing, (3) defining unscientific concepts, (4) developing an instrument prototype four-tier, (5) validation of the four-tier instrument prototype, (6) finalization of the four-tier instrument.

The four-tier instrument developed was validated by two experts using a validation sheet developed by researchers. The valid four-tier instrument was then tested on 30 Science Education study program students to determine its validity and reliability values. Test results data in the form of students' answers to the four-tier instrument are given a score of 1 if they are correct in the first tier accompanied by a confident level of confidence in the second tier and correct in the third tier accompanied by a confident level of confidence in the fourth tier; otherwise, the answer will receive a score of 0 (Rohmanasari & Ermawati, 2019). Student answer scores were analyzed using SPSS to determine validity and reliability values.

## Finding and Discussion

The four-tier instrument at the first intermediate level of chemistry concept was developed with the following stages:

### *Concept Mapping*

At this stage, the chemical material contained in science subjects (2013 curriculum) in junior high schools was analyzed. The analysis results obtained a first intermediate-level chemistry concept map in Figure 1. The question indicators were obtained based on the concept map presented in Table 1. These indicators were then developed into 30 questions and used at the Testing stage.

Table 1. Questions Indicators

Concept	Question number	Concept	Question number
Material Clasification	10	Physical change	19
Element	1,3	Chemical change	20
Compound	5	Mass conservation	11,12,27, 28
Homogeneous Mixture	8	Material separation	13, 14
Heterogeneous Mixture	9	Ionic compound	21, 25
Particle material	2,4,6,7,26	Ionic compund naming	22
Intensive properties	15	Covalent compound	23
Ekstensive properties	16	Covalent compund naming	24
Chemical properties	17	Solution	29
Physical properties	18	Solution concentration	30

## Development of Four-Tier Instrument...

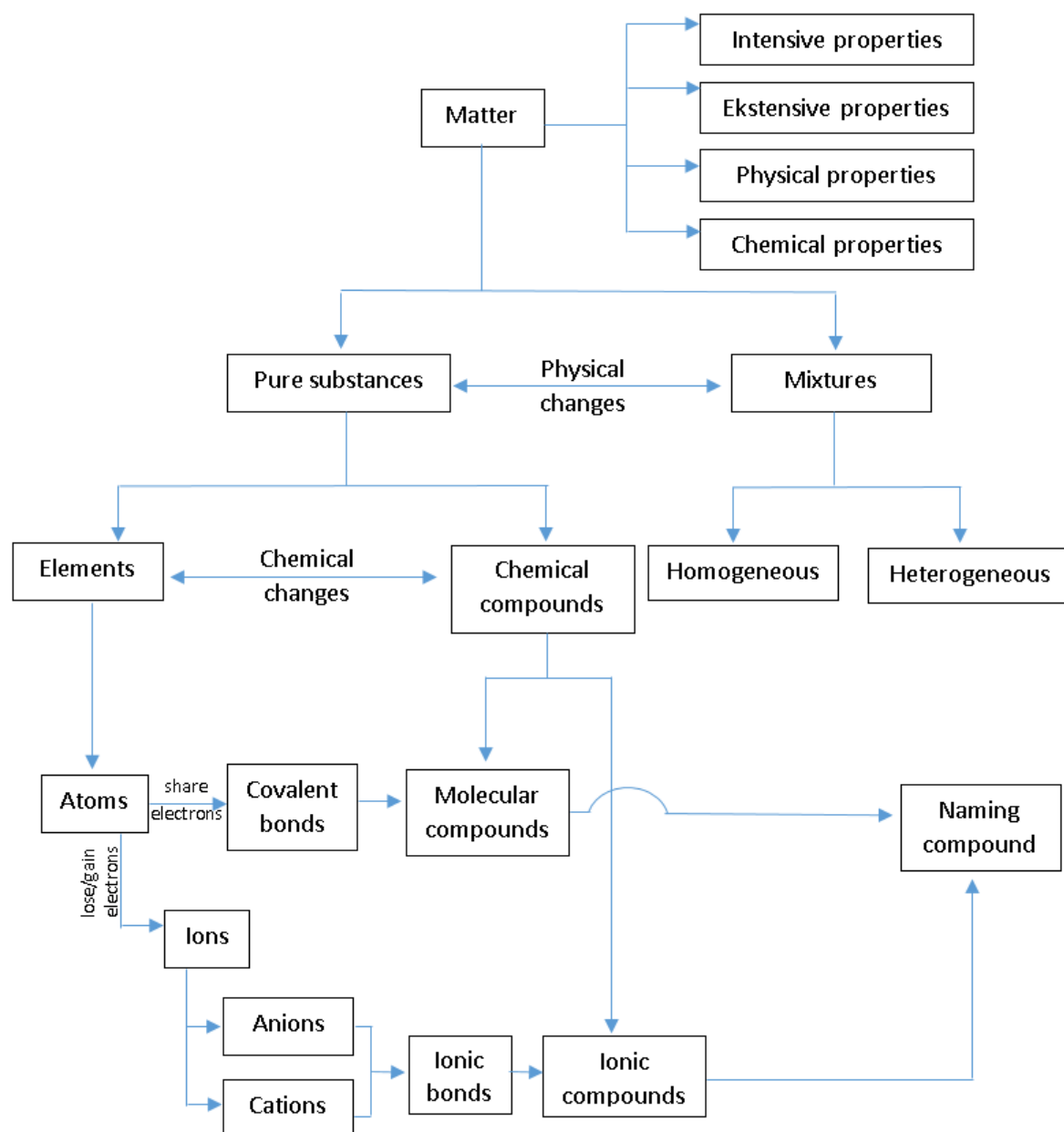


Figure 1. Middle School Chemistry Concept Map

### Testing

The questions obtained in the previous stage are initial test instruments that explore unscientific concepts held by students. The test instrument is open, where each answer choice must be given a reason by the student. Examples of testing questions can be seen in Figure 2.

Zat F tersusun atas partikel-partikel yang sejenis (sama). Ketika zat F dipanaskan mengalami proses pemisahan menjadi zat C dan T. Berdasarkan ilustrasi tersebut, maka zat F adalah ....

- A. Alloi (paduan logam)
- B. Unsur
- C. Senyawa
- D. Larutan
- E. Campuran heterogen

Alasan jawaban:

.....

.....

Figure 2. Example Testing Question

### Concept definition of unscientific

The results of testing the initial questions on 20 students of the Hasyim Asy'ari University Science Education study program obtained several unscientific concepts presented in Table 2. However, not all students' unscientific concepts can be used in the four-tier instrument development stage.

Table 2. Scientific Concept and Unscientific Concept Junior High School

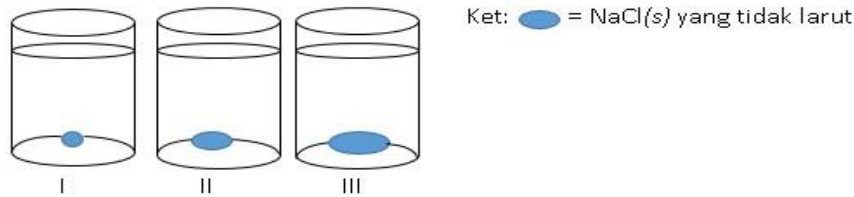
No	Scientific Concept	Unscientific Concept
1	Elements are substances that cannot be broken down into simpler substances	Elements are substances that are symbolized by one type of symbol.
2	A homogeneous mixture is a substance whose composition is the same in every part of the mixture.	A homogeneous mixture is a substance that has components its constituents cannot be distinguished.
3	Ionic bonds are bonds that occur between positive ions and negative ions.	Ionic bonds are bonds between metals and non-metals.
4	Physical changes are changes that do not cause changes in the composition of the constituent substances.	Physical changes are changes that can return to the original state.
5	Chemical changes cause changes in the composition of the constituent substances.	Chemical changes cause changes in the shape and color of substances.
6	The solubility of substances is constant at the same temperature and volume.	The solubility of a substance depends on the amount of substance dissolved.
7	The mass of the substance before the reaction is the same as the mass after the reaction.	The mass of the substance decreases due to the reaction.
8	Chemical properties are properties that cause changes in the composition of substances.	Chemical properties cause physical changes in substances.
9	The size of the atom is different from the size of the ion.	The size of the atom is always the same as the size of the ion.

### Prototype Development of Four-Tier Instrument

Based on the results of unscientific concept mapping, a four-tier test instrument prototype was developed. The development results obtained were a four-tier test instrument with 30 questions. An example of a four-tier instrument is presented in Figure 3.

## Development of Four-Tier Instrument...

Sejumlah 40, 45, dan 50 g NaCl dimasukkan ke dalam 3 gelas secara berurutan I, II, dan III yang masing-masing berisi 100 mL air pada suhu 25°C, sehingga menghasilkan larutan jenuh seperti berikut:



Pernyataan yang tepat tentang kelarutan NaCl dalam ketiga gelas adalah ....

- A. Kelarutan NaCl pada gelas I > II > III
- B. Kelarutan NaCl pada gelas III > II > I
- C. Kelarutan NaCl pada gelas II > I > III
- D. Kelarutan NaCl pada gelas II > III > I
- E. Kelarutan NaCl pada gelas I = II = III

Tingkat keyakinan jawaban: (1) Yakin                      (2) Tidak yakin

Alasan jawaban:

- 1) Semakin banyak NaCl yang mengendap maka kelarutannya kecil
- 2) Semakin besar jumlah NaCl yang dilarutkan maka kelarutannya kecil
- 3) Semakin sedikit jumlah NaCl yang dilarutkan proses kelarutan cepat
- 4) Pada suhu dan volume sama maka kelarutannya sama
- 5) Kelarutan dipengaruhi banyaknya zat yang dilarutkan

Tingkat keyakinan alasan: (1) Yakin                      (2) Tidak yakin

**Figure 3. Example of Four-Tier Instrument**

### *Validation of four-tier prototype instrument*

Validation consists of content validation and empirical validation. Two four-tier instrument experts carried out content validation. The content validation results are presented in Table 3. The validation results criteria refer to [Riduwan & Akdon \(2013\)](#).

**Table 3. Result of Content Validation of the Four-Tier Instrument**

Validation	Aspect	Score Validator		%	Criteria
		1	2		
Content	Suitability of question items to the material	4	4	93,75%	Very valid
	Correspondence of question items with question indicators	4	4		
	Suitability of question items to the sequence of material	4	4		
	Clarity of question boundaries and clarity of reasons	3	3		
Construct	Clarity of test instructions	4	4	90,00%	Very valid
	Conformity of question items to Bloom's Taxonomy	3	4		
	The accuracy of the items in identifying misconceptions	3	3		
	Distractors are rational and homogeneous	4	3		
	The image corresponds to the problem presented	4	4		

Language	Use good and correct language	4	4	91,67%	Very valid
	Language does not give rise to multiple interpretations	3	3		
	Sentences are clear and communicative	4	4		
<b>Average</b>				<b>92,81%</b>	<b>Very valid</b>

The prototype of four-tier instrument was then subjected to empirical validation testing to determine the question items' validity and reliability. The results of testing on 30 samples obtained the validity value of each question item, as presented in Table 4. The question item is valid if the calculated r-value is  $> r$  table. The results of calculations using SPSS show the calculated r-value, then compared with the r table for  $N = 30$  of 0.361

**Table 4. Validity results of Four-Tier Instrument items**

Item	1	2	3	4	5	6	7	8	9	10
<b>r Count</b>	0,611	0,417	0,564	0,524	0,604	0,525	0,508	0,580	0,640	0,521
<b>Validity</b>	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid
Item	11	12	13	14	15	16	17	18	19	20
<b>r Count</b>	0,381	0,425	0,525	0,536	0,120	0,290	0,536	0,105	0,580	0,520
<b>Validity</b>	Valid	Valid	Valid	Valid	Invalid	Invalid	Valid	Invalid	Valid	Valid
Item	21	22	23	24	25	26	27	28	29	30
<b>r Count</b>	0,495	0,392	0,450	0,521	0,460	0,434	0,457	0,534	0,690	0,457
<b>Validity</b>	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Based on the results of testing the validity of the questions, three questions were found to be invalid because the calculated r-value  $< r$  table. The three questions, no. 15, 16, and 18, could not be used, so only 27 questions were obtained. Next, reliability testing is carried out on valid question items. The reliability test results show a Cronbach's alpha value of 0.713. It means the four-tier instrument has good reliability values ([Habidin et al., 2020](#)).

### *Finalization of Four-Tier Instrument*

At this stage, revisions were made to the four-tier instrument based on the results of empirical validation. The presence of invalid questions means that the questions cannot be used. Validity is fundamental because it refers to whether the information obtained from a test represents the actual understanding of test takers ([Airasian, 1994](#)). The final results were a four-tier instrument on chemistry concepts at the junior secondary level, totaling 27 questions. This instrument is suitable for use because it is valid and reliable ([Sugiyono, 2015](#)). Validity and reliability are two parameters that can represent the quality of an instrument ([Kimberlin & Winterstein, 2008](#)).

### **Conclusion**

The result show that developing a four-tier instrument on chemistry concepts at the junior secondary level consisted of 27 questions with a validity value of 92.81% with very valid criteria and reliability based on a Cronbach alpha score of 0.713 with good criteria. Thus, the four-tier instrument is suitable for identifying misconceptions in junior secondary-level chemistry concepts.



The advantage of the four-tier instrument is that it is developed using all the chemistry concepts found in science subjects in junior high school. The weakness of the instrument that has been developed is that it is paper-based, so it is less efficient in using and processing the data obtained. Suggestions that can be given based on the results of this research are the need for further research related to the development of four-tier instruments based on digital applications.

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