Development of Chemistry Instructional Tools and Its Effect on Critical Thinking Skills, Metacognition, and Concept Mastery of Students

To cite this article: Muhammad Danial et al 2018 J. Phys.: Conf. Ser. 1028 012041

View the article online for updates and enhancements.
Development of Chemistry Instructional Tools and Its Effect on Critical Thinking Skills, Metacognition, and Concept Mastery of Students

Muhammad Danial¹, Muhammad Sawal² and Nur Lela³

¹Department of Chemistry, Universitas Negeri Makassar, Makassar, 90222, Indonesia,
²Senior High School, Bantaeng, 92461, Indonesia
³Department of Engineering, Universitas Negeri Makassar, Makassar, 90222, Indonesia

muh_niels@yahoo.com

Abstract: The aim of this research is to produce senior high school chemistry instructional tools based on investigations which is valid, practical, and effective and can empower critical thinking skills, metacognition, and mastery of buffer solution chemistry concepts for students. The method used are 1) the initial observation, 2) arranging the draft of instructional tool, 3) the development and verification of instructional tools, and try out and dissemination. The developmental phase in this research refers to the developmental model of 4-D (define, design, develop, and disseminate). Subject of the research are students class XI from state Senior High School (SHS) Bantaeng regency for limited try out test and chemistry teachers of SHS that amount 15 persons from Makassar city, Maros, Gowa, and Takalar regency for disseminate test phase. The research is 1st and 2nd year researches of plan 3 years. The first year is limited trial test and the second year is disseminated test of instructional tools. The results of the this research are obtained senior high school chemistry instructional tool based on investigations namely Investigation Lesson Plan (ILP), Investigation Model Book (IMB), and test and non-test instruments which are valid, practical, and effective based on the results of limited trial and disseminate test. The research result also shows the critical thinking skills and metacognitive of students generally are in the medium and begin to develop category, and concept mastery for buffer solution with high category. Furthermore, the teachers’ responds toward ILP and IMB are positive and practice category.

1. Introduction
Among students of Senior High School (SHS), the subjects of Chemistry is not a favorite lesson, if not arguably less attractive as a lesson for students in general. Interview glance with some students in high school will be a place or school this research also reinforces the assumption above. They are generally quickly bored with a chemistry material by rote of concepts or laws of chemistry, formula and chemical structures, chemistry calculation and the similarities and the reaction mechanism. In addition, they generally have difficulty in integrating and applying chemical concepts into facts and everyday issues. For example in answering the questions: Explain the concept of chemistry, "why do the leaves of plants that have been plucked and stored in the open space or leaves that fall from the tree will be wither and dry?, And why the sugar dissolved in hot water more quickly dissolved
compared with dissolve in cold water? Why there are some substances such as water can conduct electricity?

For teachers coaching the chemistry lesson, the fact the problems above are also a burden, as well as students are less enthusiastic and impressed only after the value in the learning process, as well as learning outcomes are generally less satisfactory. We suspects the above problems caused by learning models that are less effective and do not train and empower student thinking skills. Although the lecture method, the 'one-way' and used over the years, has been equipped with a debriefing, to enable students to ask about the teaching materials are not conquered, but the opportunity debriefing is provided generally underused by the students, This is presumably at least for three reasons. First, students are generally reluctant to ask, perhaps because of shame if considered stupid by friends or altogether not understand so it does not know what to ask, or indeed because it is not interested in learning. Second, time to ask is usually not for long, because only at the end of the discussion. Third, students is not trained to empower their thinking skills through the use of questioning skills, information processing or through some learning model application. Because untrained then the chance of asking-answering provided does not use well.

Efforts to address learning problems chemistry, presumably based learning model of investigation (such as discovery learning) will more effectively be able to overcome these problems. The results of our research in college ([1]-[5]) showed that PBL and GI learning strategy are the two models that also investigative nuances can develop critical thinking skills, thinking metacognition, mastery of chemistry concepts, and received a positive response from students who've we taught with this model. Therefore, the research team will conduct research to further expand and deepen more, that is developing instructional tool based on investigative chemistry lesson of senior high school as an effort to foster critical thinking skills and mastery of chemistry concepts for students in senior high school.

2. Methodology

2.1. Research Subject

In generally, the method used are 1) the initial observation, 2) arranging the draft of instructional tools, 3) the development and verification of instructional tools, and try out and dissemination. Subject of instructional tool trial out test is 29 students of state Senior High School 1 Bantaeng regency in academic year 2015/2016 and 15 teachers of Chemistry of Senior High School from Makassar city, Maros, Gowa, and Takalar regency for disseminate test phase.

2.2. Design and Procedure of Development of Tool

In this research, development of design refers to 4-D model of [6]. Four phases of model development are the definition phase, design phase, develop phase, and disseminate phase. Development procedures are presented in Figure 1.

2.3. Research Instruments and Data Collection Techniques

The instrument is intended to measure the validity, effectiveness, practicality of instructional tools. The instrument used to measure the validity of the tool is review sheet or validation for expert/reviewer; to measure the practicality using managing learning observation sheet, observation sheet of instructional tools realization for chemistry teachers, and the response of teachers, and to measure the effectiveness of the tool using student response questionnaires, observation sheet of students learning activities, observation sheets of students critical thinking skills, metacognition, and mastery tests of chemistry concepts for students. The data collection is done by filling out the sheet review/validation [7], the observation sheet of management and learning realization [8], gives a test to measure mastery of chemistry concepts ([9], [10], [11]), critical thinking skills sheet and metacognition ([12], [13], and [14]), realization of ILP [15], the metacognition questionnaire [16], and the response questionnaires of the students and teachers toward the instructional tool [17].
Figure 1. Procedure of Senior High School Chemistry Instructional Tool Development Based on Investigation

2.4. Processing and Data Analysis Techniques
This research data is processed and analyzed descriptively ([18], [19]) includes validation or review results data, the management of learning, activity of students, data analysis of test result of chemistry concepts mastery [20], the data of critical thinking skills, metacognition (questionnaire MAI), realization of instructional tool, and the response questionnaires of students and educators/teachers toward instructional tool.

Criterion of tool validity refers to Gregory standard index [18], the practicality of the tool refers to [18] with the level of realization of to the tool 50% of at least 70% of aspects observed, and the effectiveness of the tool refers to coefficient reliability by Boris in Trianto [21].

3. Results and Discussion

3.1. Process of instructional tool development
The process of senior high school chemistry instructional tool development based on investigation refers to 4-D model of [6]. This model includes four phases namely define, design, develop (conducted on 1st year), and disseminate (conducted on 2nd year). Based on the validation results of the instructional tools stated that the senior high school chemistry instructional tool that has been designed it classified as valid category with average of validity of the instructional tool is 3.47 with valid category (Table 1).
Table 1. Validation results of the instructional tools

| Tool                          | Indicator                                           | Appraisal | Categories of validity |
|-------------------------------|-----------------------------------------------------|-----------|------------------------|
| Investigation Lesson Plan (ILP) | 1. Specifying of learning objectives                 | 3.50      | Very Valid             |
|                               | 2. Learning material                                 | 3.80      | Very Valid             |
|                               | 3. Language and sentences                            | 3.50      | Very Valid             |
|                               | 4. Facilitation and teaching aids                    | 3.50      | Very Valid             |
|                               | 5. Methods and learning activities related to CTS and metacognition | 3.37 | Valid                   |
|                               | 6. Time allocation                                   | 3.50      | Very Valid             |
|                               | 7. Assessment/bill                                   | 4.00      | Very Valid             |
| Average                       |                                                     | 3.59      | Very Valid             |
| Investigation Model Book (IMB) | 1. Transition of concept                             | 3.50      | Very Valid             |
|                               | 2. Language and Writing                              | 3.65      | Very Valid             |
|                               | 3. Construction                                     | 3.50      | Very Valid             |
|                               | 4. Characteristic of sub concepts                    | 3.50      | Very Valid             |
| Average                       |                                                     | 3.54      | Very Valid             |
| Investigation Student Worksheet (ISW) | 1. Presentation of Problems     | 3.00      | Valid                   |
|                               | 2. Language and writing                              | 3.60      | Very Valid             |
|                               | 3. Scope of research                                | 3.50      | Very Valid             |
|                               | 4. Presentation of activities                       | 3.50      | Very Valid             |
| Average                       |                                                     | 3.40      | Valid                   |
| Critical Thinking Skills      | 1. Objectives                                       | 3.50      | Very Valid             |
|                               | 2. Construction and problem instructions             | 3.12      | Valid                   |
|                               | 3. Language                                         | 3.33      | Valid                   |
|                               | 4. Time                                             | 3.00      | Valid                   |
|                               | 5. Scope of research                                | 3.50      | Very Valid             |
| Average                       |                                                     | 3.40      | Valid                   |
| Concept Mastery Test          | 1. Objectives                                       | 3.50      | Very Valid             |
|                               | 2. Construction                                     | 3.00      | Valid                   |
|                               | 3. Language                                         | 3.33      | Valid                   |
|                               | 4. Time                                             | 3.00      | Valid                   |
|                               | 5. Scope of research                                | 3.50      | Very Valid             |
| Average                       |                                                     | 3.29      | Valid                   |
| Student Response Questionnaires | 1. Objectives                                     | 3.25      | Valid                   |
|                               | 2. Construction of statement                        | 3.00      | Valid                   |
|                               | 3. Language                                         | 3.50      | Very Valid             |
|                               | 4. Scope of Components                               | 3.50      | Very Valid             |
| Average                       |                                                     | 3.27      | Valid                   |
| Observation Sheet of          | 1. Objectives                                       | 3.50      | Very Valid             |
|                               | 2. Construction                                     | 3.50      | Very Valid             |
| Average                       |                                                     | 3.31      | Valid                   |
Tool & Indicator & Appraisal & Categories of validity \\
--- & --- & --- & --- \\
Lesson Plan Realization & 3. Language & 3.50 & Very Valid \\
 & 4. Time & 3.50 & Very Valid \\
 & 5. Scope of Components & 3.50 & Very Valid \\
Average & & 3.50 & Very Valid \\
Observation Sheet of Learning Management & 1. Initial activity & 4.00 & Very Valid \\
 & 2. Core activity & 3.95 & Very Valid \\
 & 3. End activity & 4.00 & Very Valid \\
 & 4. Time management & 3.75 & Very Valid \\
 & 5. Asking technique & 3.62 & Very Valid \\
 & 6. Class condition & 4.00 & Very Valid \\
 & 7. Use of Media & 4.00 & Very Valid \\
Average & & 3.90 & Very Valid \\
Teacher Response Questionnaire & 1. Objectives & 3.50 & Very Valid \\
 & 2. Construction & 3.50 & Very Valid \\
 & 3. Language & 3.50 & Very Valid \\
 & 4. Scope of Components & 3.50 & Very Valid \\
Average & & 3.50 & Very Valid \\
Average & & 3.47 & Valid \\

3.2. Try Out of Instructional Tool Validation Results
The revised instructional tool was tried out to students of state Senior High School Tompobulu Regency of Bantaeng of academic year 2015/2016. Limited try out of the tool includes aspects of the use of the tool in the learning process, giving a test to measure the student critical thinking skills and concepts mastery, filling the realization observation sheet of ILP and management of learning by the observer, and giving the students and teachers response questionnaires. The data obtained in this trial was processed and analyzed to use in assessing the effectiveness and practicality of the trial out result instructional tool. Results of limited trial out of instructional tools are presented in Table 2.
Table 2 shows that the instructional tool has valid, effective, and practical criteria so that it can be implemented more widely namely disseminate phase.

3.3. Developmental Product of Instructional Tool Based on Investigation
The disseminate test phase has been conducted with giving teachers response questionnaires to 15 chemistry teachers of SHS. The results of the disseminate test phase are obtained that SHS chemistry instructional tool based on investigations namely ILP, IMB, and test and non-test instruments which are practical, effective, and teachers ‘responds with positively and practice category. Data of disseminate results are presented in Table 3.
Based on the perception of teacher in the disseminate phase can be stated that the instructional tool is classified as good or in another word the teachers responded positively to the instructional tool products of this development results.

| Observation Object and Appraisal based on the learning tools and test and non-test instruments | Realization/Use, Acquisition Scores and achievement | Category |
|---|---|---|
| Realization of ILP | Done entirely | Good and practical |
| The use of IMB | Used well | Good and practical |
| The use of ISW | Used well | Good and practical |
### Observation Object and Appraisal based on the learning tools and test and non-test instruments

| Observation Object | Realization/Use, Acquisition Scores and achievement | Category |
|---------------------|----------------------------------------------------|----------|
| Concept mastery     | • 68.97% of high category.  
• 96.55% students is complete with average value of 86.72 | Effective and high category |
| Learning management | The average observation is 3.93 (for 5 components and maximum score 4.00) | Very high and effective |
| Critical Thinking Skills | 93.10% | Medium and effective |
| Student responses   | 82.76% | Positive responses and effective to study chemistry |
| Teacher responses   | 100% | Attracted, motivated, and effective for teaching chemistry |
| Metacognition       | 83.25% | Begin to develop |

### Table 3. Result of disseminate test for instructional tools

| Tools                                    | Categories of conducting | Categories of perception |
|------------------------------------------|---------------------------|--------------------------|
| Investigation Lesson Plan                | Can be conducted          | Positive and Practice    |
| Investigation Model Book                 | Can be used               | Positive and Practice    |
| Investigation topic Instrument          | Can be conducted          | Positive and Practice    |
| Test Instrument for Concept Mastery of Buffer Solution | Can be used | Positive and practice |
| Investigation Student Worksheet (ISW) Instrument | Can be used | Positive and practice |
| MAI instrument                          | Can be used               | Positive and practice    |
| Aspects in Critical Thinking Skill Instrument | Can be used | Positive and practice |

Furthermore, the perception of senior high school chemistry teacher on the instructional tools namely ILP, IMB, ISW, Topics of investigation, test and non-test instrument classified interesting and newness category is high.

The all of instructional tools called is practice because it can be used with easy by chemistry teachers for applied and to guided students, and it can involve all students actively in learning process. The instructional tools called is effective because it can increasing critical thinking skill,
metacognition, mastery of concepts of students and called is positive because the instructional tools can be received well by the teachers to implementation in the senior high school.

The all of instructional tool called is interesting because the chemistry teachers feel content with presence the discovery learning tools based investigation and very interest to implementation in the class and also the instructional tools is new for chemistry teachers.

Based on data from the validation of expert, limited trial out test, and disseminate results of instructional tools can be stated that the senior high school chemistry instructional tools based on investigation have valid, effective, practical criteria, and well appreciated by chemistry teachers, so that the instructional tools can be to implementation in the broader level and it compare with others instructional tools.

4. Conclusion

The development phases of chemistry instructional tools refers to the 4-D patterns by Thiagarajan includes define, design, develop, and disseminate of instructional tools. From the results of this process have been obtained (1) instructional tools in the form of ILP, ISW, IMB, and test and non-test instruments are valid, effective, and practical category, (2) the use of instructional tools based on investigation on the level of was able to develop the critical thinking skills of students and improve the level of mastery of concepts in chemistry subjects (buffer solution concept), and (3) based on the appreciation or the perception/responds of senior high school chemistry teachers can be stated that the instructional tools classified as good or in another word the teachers responded positively to the instructional tool products of this development results.

These instructional tool products still need to implementation in SHS and its comparing with the others model/instructional tool via experiment research widely to obtain information that more and more powerful that will be obtained more perfect instructional tools than instructional tools exist today.

References

[1] M. Danial. 2008 Pembelajaran Berbasis Investigasi dan Metakognisi. Seminar MGMP Biologi SMA di kota Malang, November 15th
[2] M. Danial. 2008 Pembelajaran, Metakognisi, dan Hasil Belajar Kimia Dasar (Suatu Survei terhadap Staf Pengajar Kimia Dasar dan Mahasiswa jurusan Biologi Angkatan 2007/2008 FMIPA UNM Makassar). J.Bioedukasi Vol. VI, 2 170-178.
[3] M. Danial, Husain, E. L. Allo, E.L. 2011 Respon Mahasiswa terhadap Penerapan Strategi PBL, GI, dan integrasi Kooperatif PBL-GI. Laporan Penelitian PNBP UNM
[4] M. Danial, Nurlaela. 2014 Pengembangan Perangkat Pembelajaran Kimia Dasar untuk Biologi Berbasis Group Investigation sebagai Upaya Menumbuhkan Metakognisi dan Penguasaan Konsep. Laporan Penelitian Hibah Bersaing Tahun 1 UNM
[5] M. Danial, Nurlaela. 2016 Pengembangan Perangkat Pembelajaran Kimia SMA Berbasis Investigasi dan Pengaruhnya terhadap Keterampilan Berpikir Kritis, Metakognisi dan Penguasaan Konsep Peserta Didik. Laporan Penelitian Hibah Bersaing Tahun 1 UNM
[6] S. Thiagarajan, D. S. Semmel, M. I. Semmel. 1974 Instructional development for training teachers of exceptional children. Minneapolis, Minnesota: Leadership Training Institute/Special Education, University of Minnesota
[7] A. Jihad, A. Haris. 2008 Evaluasi Pembelajaran. Jakarta: Multi Presindo
[8] Tim Bio. 2008 Jurnal Belajar Biologi. Malang: YPUM SMA LAB
[9] L.R. Anderson, D. R. Krathwohl. 2001 A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives. A Bridged Edition. New York: Addison Wesley Longman, IncD.
[10] W. Oxtoby, Gillis, H. N. Norman. 2010 Principles of Modern Chemistry, Fourth edition. USA: Harcourt Inc.,
[11] R. H. Petrucci. 1985 Kimia Dasar: Prinsip dan Terapan Modern (Jilid 1). Terjemahan oleh
References

[12] Schraw, R. S. Dennison. 1994 Assessing Metacognitive Awareness. Contemporary Educational Psychology, 19 460-475.

[13] R. H. Ennis, RH. 1996 Critical Thinking. USA: University of Illionis

[14] A. L. Costa. 1985 Developing Minds A Resources Book for Teaching Thinking. California: Association for Supervision and.Curr. Development

[15] Susanto. 2008 Penyusunan Silabus dan RPP Berbasis Visi KTSP. Surabaya: Mata Pena

[16] J. A. Livingston. 1997 Metacognition: An Overview, (Online), (http://www.gse.buffalo.edu/fas/shuell/cep564/Metacog.htm, accessed on Desember 20th, 2007).

[17] Subandi, E. Susanti. 2005 The Effectiveness of Problem-Based Learning Method in Biochemistry Learaning. Prosiding Seminar Nasional MIPA dan Pembelajarannya & Exchange Experience of IMSTEP 5-6 September 2005. Malang: FMIPA UM - Dirjen Dikti depdiknas.

[18] S. Arikunto. 2006 Prosedur Penelitian: Suatu Pendekatan Praktik. Jakarta: Rineka Cipta

[19] Gaspersz. 1991 Metode Perancangan Percobaan untuk Ilmu-Ilmu Pertanian, ilmu-ilmu Teknik, dan Biologi. Bandung: Armico

[20] D. Hart. 1994 Authentic Assessment A hand Book for Educators. New York: Addison-Wesley publ.Co,

[21] Trianto. 2009 Mendesain Model Pembelajaran Inovatif Progresif: konsep landasan dan implementasinya pada KTSP. Jakarta: Kencana