Possibilities of dynamic assessment to enhance students’ understanding on abstract science concepts: a systematic review

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Abstract. Dynamic assessments (DA) had been widely used in language and mathematics learning, but its use in science learning is still limited. One difficulty faced by students in science learning is the sheer number of abstract concepts. This literature review was aimed to find out the prospect of DA in science learning to improve students’ understanding of abstract scientific concepts. This study analyzed various learning topics used with DA, the types of DA instruments, and procedures to train students’ conceptual understanding. The PRISMA was used as the research method. The results showed the DA has been used in learning ecology, biology, atmosphere and water, evolution, and classification, photosynthesis, and weather and climate. It showed DA can improve students’ conceptual understanding. Implementing DA in the learning process can be done by providing additional explanations or training to students. The types of instruments for DA were varied, such as tests, questionnaires, and interviews with semi-structural forms. We recommend the usage of DA to improve student understanding regarding abstract science concepts, especially biology.

1. Introduction

Scientific concepts and phenomena, such as in biology, can be found around us. Biological phenomena are found in humans, plants, animals, and even microorganisms, all of them can be sensed by humans. These facts can be searched for their correlations, similarities, and differences, so we can categorize and group the living things based on observed morphological and behavioral facts. However, not everybody can explain at a more abstract level why those differences and similarities occurred, or explaining why a biological behavior occurred and how about their process.

How biology teacher can to help students to understand these abstract concepts? Some studies provided conclusions that simulations, observations of processes through video or animation [1], interviews [2], observations [3], demonstrations [4] and practicums, both with manual [5] or virtual laboratories [1], can be used to improve students’ conceptual understanding.

One strategy to help students understand abstract concepts is through assessment. Based on Vygotsky’s Zone proximal development (ZPD) theory, each child has a development zone achievable
only with the help of others [6]. Using the same logic, understanding abstract concepts in biology can be achieved through assistance for ZPD. Each student has dynamic cognitive abilities which require different time frames and techniques to understand the concept [7], [8]. On that basis, learning assessments can help students to improve their cognitive learning abilities.

Students’ cognitive abilities to understand abstract concepts can be improved through dynamic assessment (DA). DA gives the opportunity for students to understand abstract material concepts through additional explanations or emphasis on the learned concepts [7], [9]. DA help them overcome their learning problems, improve their conceptual understanding and cognitive abilities [7], [9]. DA is a learning assessment to help students understand concrete and abstract concepts [10].

The development of DA use in science education should be studied, because so far DA is widely used in language education, especially to improve students’ vocabulary, writing [11], and reading skills [12] and the skill to apply mathematical formulas [9]. It’s potential to help students understand abstract scientific or biological concepts still should be studied. This literature review was conducted to find out the prospect of DA to improve students’ understanding of abstract concepts. The research questions were: 1) what the learning materials used in DA research? 2) How DA trains students’ conceptual understanding? And 3) what kind of DA instruments have been used and developed?

2. Methods
The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) was used as the research method. The articles were searched through online databases using three main keywords: dynamic assessment, learning, and concepts. The online databases used were: Science direct (52), JSTOR (142) and Eric (23). The search yielded 217 journal articles. The main keywords were combined to get the relevant articles. The articles were limited to the reviews and research papers.

The articles were then screened and limited to the primary and secondary education level, and 33 articles were yielded. The paper then reviewed by the author’s team and scored according to inclusion criteria. The inclusion criteria chosen were: learning material, instrument form, and DA procedures.

The review with inclusion criteria yielded 10 articles. From further examination on the entire article, we decided to discuss DA research from three main authors who conducted consistent research on DA: Wilma C. M. Resing [13]–[16], Pi-Hsia Hung [17]–[20], and Tzu-Hua Wang [21]–[26]. The articles from the authors were tracked further, and their consistent research articles on DA were obtained. The results of analysis from 14 articles (retained) were the summarized and then interpreted to answer the research questions.

3. Result and Discussion
3.1. results of articles analysis.

| Authors and Research | Aims and Participants | Procedures of DA | Types of DA Instruments |
|----------------------|-----------------------|------------------|-------------------------|
| Wilma C.M. Resing, et al. (2009; 2013, 2016a, 2016b); DA for analogical reasoning of diverse children cultural background) [13]–[16]. | To find out the effect of DA on analogical reasoning abilities of students from diverse cultural background in Netherlands. Participants: first and second grade of | Research design: Pretest-training-post-test control-group designs with randomized blocking. Groups of treatment: (1) Graduated prompt (pretest-DA training-post-test); (2) Practice Control (pretest-no training and feedback-post-test); (3) Attention Control (pretest-a maze coloring task-post-test). | (1) The Serial-Think of seriation and early math skills such as estimation, measuring, counting, addition, subtraction. (2) AnimaLogica Test: A figural analogy with points of the analogical test: animal, color, size, position, quantity, and orientation. (3) Test: Multiple choices (4 boxes with three of with |
| Authors and Research | Aims and Participants | Procedures of DA | Types of DA Instruments |
|----------------------|-----------------------|------------------|-------------------------|
| P. H. Hung, et al. (2010a, 2010b, 2012a, 2012b); A concept-map integrated dynamic assessment system for improving ecology observation competences in mobile learning activities. | To find out the differences between gifted and average students in ecological observation, with the provision of DA intervention integrated with concept maps in mobile-based learning. | Procedures: Pretest: Children were asked to name the animal and explain what changed; Training: graduated prompt was five layers, if students answered incorrectly (first two levels of metacognitive skills on cognitive training; and the third to fifth prompt are for cognitive process of solving the analogical reasoning. | animal drawings, and one box is empty) (4) The optional answers are: Correct answer Partial answer, missing one transformation and non-analogical answer, duplication or missing two transformations. |
| Participant: fifth and sixth grade students. | CIDAS (Concept-Map Integrated Dynamic Assessment System) and Computerized Ecology Observation Competence Assessment (CEOCA) | Concept map integrated ecology observation worksheets; Three layers of instruction and tasks: (1) Guided observation with one-level concept map tasks; (2) autonomous observation with two-level concept map tasks; (3) Scientific inquiry with three level concept map tasks. | |
| T. H. Wang, et al. (2004, 2007, 2008, 2010, 2011 and 2017); Usage of Web-based dynamic assessment for effective learning [21–26] | To compare and find out the effectiveness of Web-based Assessment and Test Analysis system (WATA), normal Web-based test (N-WBT). | Quasi experimental design; Groups of treatment: Gradual prompt; Procedures of DA: (1) N-WBT (Normal-Web-based tests): Web-based assessment without prompting. (2) WATA: Explanations of problems, helping learners to clarify conditions Explanation; key Concepts; Demonstrating how to solve a similar problem with simplified numbers or performing direct instruction. Modified WATA | (1) User Satisfaction Survey of the WATA system (USSW) in triple “A” (assembling, administering, appraising). (2) Survey of Assessment Perspectives (SAP). (3) WATA Formative Assessment Strategies Scale (WFASS). (4) Multiple-choice tests with un-repetitive items for formative assessment and summative assessment. (5) Hidden Figures Test (HFT) to find out students’ cognitive style. (6) Assessment Knowledge Test (AKT) to assess |
Authors and Research  
Aims and Participants  
Procedures of DA  
Types of DA Instruments

and seventh-grade students in Taiwan.

Topics materi: Atmosphere and water, evolution and classification, photosynthesis, weather and climate, basic mathematics

- GPAM-WATA (Graduated Prompting Assessment Module of WATA System)
- Triple-A WATA (WATA System in: assembling, administering, appraising)
- FAM-WATA (Formative Assessment Module of the Web-Based Assessment and Test Analysis System)
- PDA-WATA (Peer Driven Assessment Module of the Web-based Assessment and Test Analysis System)

(3) PPT group (paper-based test manual); prompt by teachers’ explanations.
(4) Training on WBI (Web Based Instruction) and WATA, concluded with the post-test, the results analyzed using SAP (Survey of Assessment Perspectives).
(5) Practicing, Reflecting and Revising Assessment Literacy Development Model (P2R).

in-training pre-service teachers.
(7) WATA.
(8) GPAM-WATA
(9) Achievement tests and two-tier diagnostic tests.
(10) PDA-WATA.
(11) N-WBT.
(12) E-learning materials.

3.2. The topic used on the research about dynamic assessments

The abstract scientific concepts complicate the students to understand them. DA on science education had been researched by various researchers, such as: Wilma C.M. Resing, et al. (2009, 2013, 2016a, and 2016b); Hung, Pi-Hsia et al. (2010a, 2010b, 2012a, and 2012b); and T. H. Wang, et al. (2004, 2007, 2008, 2010, 2011 and 2017) (table 1). The samples and participants were varied, including: kindergarten [15] primary school students and teachers [13], [14], [16], [17]; seventh-grade students [22], [25]–[27]; pre-service biology teachers [21], [23], and science teachers [21], [22], [25]. The research designs were varied, including: Pretest-training-post-test control-group with randomized blocking [13]–[16]; and Quasi experimental [21]–[27].

Science learning covered both concrete and abstract topics. The topics used in DA research were varied from atmosphere and water [22]; evolution [23], [25] and classification [23]; Photosynthesis [24]; and weather and climate [26]. Various research concluded the learning with DA was more effective and help to improve students’ understanding of abstract scientific concepts [21]–[26].

The students’ understanding of abstract concepts showed their cognitive developments. Students’ cognitive developments were dynamic and developed from concrete to abstract understanding [13]–[16]. Students’ cognitive developments were affected by their biological developments (ages) and learning process [6], [8], [10]. Helps from other, like additional explanations or instructions can help students improve their understanding of abstract concepts [21]–[27].

3.3. Procedures of dynamic assessment

Unlike static assessments, DA has distinctive characteristics, such as 1) the students were provided with additional treatment or explanation [13]–[16]; 2) focused on students’ conceptual understanding [21]–[27]; and 3) examiners and examinees can have interaction during the assessment process [12]. In DA,
teachers act as facilitators. They can provide exercises or brief explanations during the exam or learning. Training or information obtained by students help them develop their learning abilities.

Dynamic changes in students’ skills and understanding can be identified by comparing their pre- and post-training skills and understanding. Their initial skills assessed through the pre-test. After the pre-test, the teacher can provide feedback, training, or explanations to improve the student’s conceptual understanding. Teachers can carry out tests on the same topic to find out student achievement. Teachers, as assessors and facilitators, can use Web applications or mobile learning to provide help and the tests.

DA gives the opportunity for teachers to improve students’ cognitive abilities. The reviewed articles showed various techniques for DA (table 1), such as: 1) gradual prompt (pretest-DA training-post test); 2) practice Control (pretest-no training and feedback-post test); and 3) attention Control (pretest-a maze coloring task-post test) [13]–[15]. Finding students’ cognitive development can be done through pre- and post tests accompanied by giving prompts by the teacher (scaffolds) [14], [24].

3.4. types of instruments for DA
Instruments for DA have several unique characteristics. Teachers can use DA to find out actual changes and developments of students’ cognitive. It also helps students to achieve maximal learning results [7], [9]. Instruments for DA can be used at various levels of students’ learning skills [13]–[16]. DA differs from static assessment which only made in the end of learning process [22].

The reviewed articles (table 1) also showed various types of instruments for DA. Those instruments were: The Seria-Think of seriation and early math skills [13], AnimaLogica test [14]–[16], integrated concept map [17]–[20], Web-based Assessment and Test Analysis system (WATA), and Normal Web-based Test (N-WBT) [21]–[27], Survey of Assessment Perspectives (SAP) [21], [23], Hidden Figures Test (HFT) [22], Assessment Knowledge Test (AKT) [23], and E-Learning [25]–[27]. Integrating modern technology with DA can be the solution in cognitive learning, especially the understanding of abstract science concepts [17], [25], [26].

4. Conclusion
DA can be used to assess students’ cognitive development, specifically their understanding of abstract concepts. DA can be used to improve students’ conceptual understanding across various education levels. Research about DA on science learning had been carried out on various topics, such as: ecology, biology, atmosphere and water; evolution and classification; photosynthesis; and weather and climate. DA can be implemented in the learning process by providing additional explanations or training to students. The DA instrument differs from the static assessment. Based on the results, we recommend for the next researcher to develop DA to improve students’ understanding of abstract scientific concepts, especially biology.

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