The use of interactive multimedia to promote students' understanding of science concepts and generic science skills

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ABSTRACT. Multimedia plays an increasing role in education, especially in science instruction. Unlike the conventional teaching media, multimedia allows flexible combination of different modes of representation, such as written text, pictures, animations, and sound. Using multimedia, teachers can use a combination of pictures and texts to explain a complex structure. Multimedia also allows a simulation of complex processes in simpler forms of animations. The research results reported here represent the first year results of a tree-year research project, which aims at developing a Web-based instruction utilizing multimedia. The aim of the first year is to develop multimedia, and to analyze its impact on the improvement of students' understanding of science concepts, and on the improvement of their generic skills. This study finds that the use of multimedia in science instruction can promote students' understanding of science concepts. Relatively high gains were observed in biology lessons (junior high school) and chemistry lessons (senior high school), while a mediocre impact was observed in the thermodynamics course (pre-service teacher training) and magnetic induction course (in-service teacher training). The use of multimedia in instruction also promotes the participants' generic science skills.

KEYWORDS: *Concept understanding, Generic science skills, Multimedia, Science*

Introduction

It is quite well-known that for many students science is a difficult subject. Results of national examination and international comparative studies clearly suggest that science education in Indonesia demands urgent improvements (OECD/UNESCO-UIS,

2003). Despite a number of policies and efforts, it seems however that the improvement does not yet meet the expectations of the stakeholders.
Science instruction should not only focus on understanding scientific concepts, but should also address skills and aptitudes that are also very important learning achievements. Brotosiswoyo suggests that science instruction can promote students' generic skills (Brotosiswoyo, 2000):

1) direct observation

2) indirect observation

3) sense of scale

4) symbolic language

5) logical consistency of natural law

6) logical inference

7) causality

8) mathematic modelling

9) developing abstract and functional concepts

One of the alternative innovations to promote students' understanding of science concepts is designing instruction curricula that make use of the recent developments in computers and information technologies. In the last few years, multimedia plays an increasing role in instruction, especially science instruction. Unlike the conventional teaching media, multimedia allows a flexible combination of different modes of representation, such as written text, pictures, animations, and sound. Using multimedia, teachers can use a combination of pictures and texts to explain a complex structure. Multimedia also allows a simulation of complex processes in simpler forms of animations. Chemical reactions, for example, are difficult science topics for students, due to their abstract nature. Using multimedia, such abstract processes can be animated, so that they may be easier to understand.
Schnotz and Lowe categorize multimedia into three different levels: the technical level (the technical devices that carry the messages, e.g. computers, networks); the semiotic level (the representational format of the messages, e.g. texts, pictures); and the sensory level

(the sensory modality of sign reception, e.g. visual, auditory). This suggests that research on the use of multimedia in instruction may either focus on a certain level or a combination of different levels (Schnotz, Lowe, 2003).

The research results reported here represent the first year results of a tree-year research project, which aims at developing a Web-based instruction utilizing multimedia. The aim of the first year is to develop multimedia, and to analyze its impact on the improvement of students' understanding of science concepts, and the improvement of their generic skills.

Methods

In order to gain information on the application of interactive multimedia in different learning conditions, participants having very different characteristics were involved in the study, i.e. junior high school students, high school students, pre-service teachers, and in-service teachers. The topics covered in the study include topics related to biology, chemistry, and physics (Table 1).

Table 1. Subjects and topics of the study

Subject	Topic
Junior high school students	Organization of life (Biology)
High school students	Hydrolysis of salt (Chemistry) Colligative proprieties of solution (Chemistry)
Pre-service teachers	Thermodynamics (Physics)
In-service teachers	Magnetic Induction (Physic)

The characteristics of concepts within the three topics are presented in Table 2. The table shows that the number of topics, and the type of concepts vary for each school level.

No.	Subject	Topic	Types of concepts
1.	Biology	• Organization of life	Concrete, abstract, concepts based on principles
2.	Physics	• Thermodynamics • Magnetic induction	Concrete, abstract, concepts based on principles, symbols, processes, and properties
3.	Chemistry	• Hydrolysis of salt • Colligative properties of solution • Ideal gas	Concrete, abstract, concepts based on principles, abstract concepts with concrete examples, processes, symbols, and properties

Table 2. Characteristics of concepts

Concrete, abstract, concepts based on principles are three characteristics shared by all topics. While the types of concepts addressed in biology are only three, the concepts addressed in physics and chemistry also include concepts related to symbols, concepts related to properties, and concepts related to processes. A quasi experiment design was employed in the study. Prior to instruction, subjects were required to do tests in order to measure their understanding of concepts, and the level of their generic science skills. During the instruction, interactive multimedia were employed, specially developed for the purpose of the study. At the end of the instruction, subjects were again required to do similar tests administered as a pre-test (Figure 1).

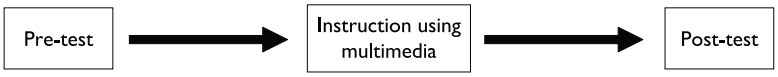

Figure 1. General design of the study

Students' achievements were measured in terms of their understanding of concepts, and their level of generic science skills. In this first research year, a number of generic science skills, as identified by Brotosiswoyo, were assessed (Brotosiswoyo, 2000). The aspects of generic science skills addressed in this study are presented in Table 3. In order to measure the effectiveness of multimedia, a pre-test and a post-test were administered.

Table 3. Generic science skills assessed in the study

Generic skills	Subject			
	Junior high school	Senior high school	Pre-service teacher	In-service teacher
Direct observation				
Indirect observation		V	V	
Sense of scale	V			
Symbolic language		V		V
Logical consistency of natural law			V	V
Logical inference	V		V	V
Causality	V	V		V
Mathematic modelling		V	V	V
Developing abstract concepts	V	V	V	V

Results and findings

Multimedia and understanding of science concepts

In order to gain information concerning the impact of multimedia on the improvement of subjects' understanding of science concepts, pre-test and post-test scores are compared for each group (Table 4).

Table 4. Scores for each group of subjects

Subject		n	Pre-test	Post-test	Test significance
Junior high school students		34	46,4	73,6	Significant
Senior school students	Hydrolysis of salt	33	34,9	80,7	Significant
	Colligative properties of solution	39	31,5	63,5	Significant
Pre-service teachers		33	44,8	57,3	Significant
In-service teachers		30	20,0	46,3	Significant

Analysis of the data reveals that there are significant improvements of students' understanding of the concepts taught using multimedia. This suggests that multimedia can be used as an alternative for improving students' understanding of science concepts.

Analysis of the gain (normalized gain) shows that the use of multimedia in instruction results in a gain of 0,33 - 0,71 (Figure 2).

Relatively high gain scores are observed in junior and high school instruction, while gains for instruction in pre-service and in-service training are relatively low. This suggests that multimedia are effective for school students, but less effective for teachers.

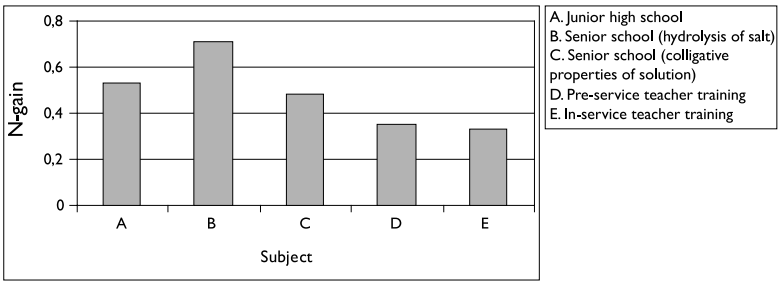

Figure 2. Scores of normalized gains for each group

Multimedia and generic skills

As discussed in the previous section, only generic skills closely related to the nature of the topics and the education levels are measured in this study. Results of the study are presented in Table 5.

Generic skills	Subject			
	Junior high school	Senior high school	Pre-service teacher	In-service teacher
Direct observation	-	-	-	-
Indirect observation	-	significantly improved	significantly improved	-
Sense of scale	significantly improved	-	-	-
Symbolic language	-	significantly improved	significantly improved	less improved
Logical consistency of natural law	-	-	significantly improved	significantly improved
Logical inference	significantly improved	-	significantly improved	significantly improved
Causality	significantly improved	significantly improved	-	significantly improved
Mathematic modelling	-	significantly improved	significantly improved	significantly improved
Developing abstract concepts	significantly improved	significantly improved	significantly improved	less improved

Table 5. The impact of multimedia on the improvement of the participants' generic skills

In general, the use of multimedia in science instruction results in a significant improvement of the participants' generic science skills. One of the interesting findings is that the use of multimedia in in-service teacher training does not always result in a significant improvement of the participants' generic skills. This result is quite similar to the results related to the improvement of the participants' understanding of concepts. As previously discussed, the use of multimedia for teachers only results in a limited gain in terms of the participants' understanding. Both findings suggest that the use of multimedia for teachers may need deeper and more careful consideration than its use for students.

Conclusion

In summary, the use of multimedia can promote the participants' understanding of science concepts as well as the participants' generic skills. It seems, however, that the use of multimedia for teachers' training needs to be more carefully developed.

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Sintesi

Il progetto della University of Education di Bandung, in Indonesia, incentrato sull'utilizzo della multimedialità per il miglioramento della formazione scientifica, della durata di tre anni, a conclusione del primo anno di svolgimento, presenta i primi risultati di ricerca, relativi allo sviluppo della formazione Web-based. L'obiettivo specifico del primo anno è quello di sviluppare mezzi multimediali interattivi, e analizzarne l'impatto sul miglioramento della comprensione di concetti scientifici e delle competenze generiche da parte di discenti appartenenti ad una tipologia differenziata: studenti di scuola media, studenti di scuola superiore, insegnanti pre-ruolo e insegnanti di ruolo.

Per misurare l'efficacia degli strumenti multimediali, si è seguito un metodo semi-sperimentale, consistente nella somministrazione di un pre-test, per un controllo preliminare della comprensione dei concetti e del livello delle competenze generiche dei partecipanti, e di un post-test, successivo alla formazione vera e propria, basata sull'utilizzo della multimedialità, per il controllo dei risultati ottenuti. I risultati del pre-test e del post-test sono poi stati comparati per ciascun gruppo.

La ricerca ha dimostrato che l'utilizzo della multimedialità nell'istruzione scientifica può di fatto favorire la comprensione di concetti scientifici, in due direzioni: da parte, miglioramenti relativamente importanti si sono infatti osservati nelle lezioni di biologia (scuola media) e nelle lezioni di chimica (scuola superiore), mentre un impatto minore si è registrato nel corso di termodinamica (formazione insegnanti pre-ruolo) e nel corso di induzione magnetica (formazione insegnanti di ruolo); dall'altra, l'utilizzo della multimedialità nella formazione favorisce notevolmente anche lo sviluppo delle competenze generiche dei partecipanti. Dunque, se l'utilizzo di strumenti multimediali sembra effettivamente migliorare la comprensione di concetti scientifici e le competenze generiche dei partecipanti, pare tuttavia che l'utilizzo della multimedialità per gli insegnanti necessiti di essere sviluppata con maggiore attenzione.

Nell'opera di Schnotz e Lowe, "External and internal representations in multimedia learning", del 2003, gli strumenti multimediali vengono categorizzati in tre livelli differenti: il livello tecnico (le attrezzature tecniche che veicolano i messaggi, come, per esempio, computer e network); il livello semiotico (il formato di rappresentazione dei messaggi, come, per esempio, testi e immagini); il livello sensoriale (la modalità sensoriale della ricezione dei segni, come, per esempio, istanze visuali e uditive).

La ricerca sull'utilizzo della multimedialità nell'educazione può quindi concentrarsi sia su un certo livello o su una combinazione di livelli differenti. Le istanze coperte nello studio comprendono argomenti relativi alla biologia, alla chimica e alla fisica. Il numero di argomenti e il tipo di concetti variano per ciascun livello scolastico; mentre i tipi di concetti trattati in biologia sono soltanto tre (concreti, astratti, basati su principi), quelli trattati in fisica e chimica comprendono anche concetti relativi a simboli, proprietà e processi. Quanto alle competenze generiche degli studenti, ne vengono misurate 9, relativamente alla natura degli argomenti e ai livelli della

formazione: osservazione diretta; osservazione indiretta; senso della dimensione; linguaggio simbolico; coerenza logica della legge naturale; inferenza logica; causalità; modellizzazione matematica; sviluppo di concetti astratti e funzionali.

In definitiva, la ricerca documenta che l'incremento normalizzato risulta pari a valori compresi tra 0,33 e 0,71. Punteggi abbastanza alti relativi agli incrementi si osservano nella formazione della scuola media inferiore e superiore, mentre i punteggi relativi agli incrementi per la formazione di insegnanti pre-ruolo e insegnanti di ruolo sono molto più bassi. Questo suggerisce che la multimedialità è efficace per gli studenti della scuola, ma meno efficace per gli insegnanti.