IMPROVING STUDENTS' REPRESENTATIONAL SKILL AND GENERIC SCIENCE SKILL USING REPRESENTATIONAL APPROACH

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Abstract: Improving Students' Representational Skill and Generic Science Skill Using Representational Approach. This one group pretest-posttest research aimed to examine the effectiveness of representational approach to improve students' representational and generic science skills through Selected Topics of School Physics course. The subjects consisted of 24 undergraduate students of physics education program of UM. The data were gathered using integrated Mechanics Baseline Test and rubric. Quantitative data analyses included t-test, Cohen's d-effect size, and normalized gain, whereas qualitative data analyses included coding, tabulating, and interpreting. This result indicated that this representational approach was considered effective to achieve both learning outcomes.

Keywords: representational approach, representational skill, generic science skill

Abstrak: **Meningkatkan Kemampuan Representasi dan Kecakapan Generik Sains Mahasiswa melalui Pendekatan Representasional**. Penelitian *one group pretest-posttest* ini bertujuan menguji keefektifan pendekatan representasional untuk meningkatkan kemampuan representasi dan kecakapan generik sains mahasiswa calon guru fisika melalui matakuliah Kapita Selekta Fisika Sekolah. Subjek terdiri atas 24 mahasiswa S-1 program studi Pendidikan Fisika UM. Data digali melalui tes dasar mekanika dan rubrik. Analisis kuantitatif meliputi t-test, *effect size*, dan gain ternormalisasi, sedangkan analisis kualitatif meliputi pengodean, penabelan, dan penafsiran. Penelitian menyimpulkan bahwa pendekatan representasional tersebut efektif mencapai tujuan yang diharapkan.

Kata kunci: pendekatan representasional, kemampuan representasi, kecakapan generik sains

History of science shows that the invention of new representations constitutes a fundamental class of advances in science (Kozma, 2000). Every generation of scientist brings new representation into play (diSessa, 2004). Scientists use representations to describe and explain observed phenomena as well as to predict new phenomena. While constructing and using knowledge, they often represent the knowledge in different ways, check for consistency of the representations, and use one representation to help construct another (Etkina et al., 2006). They use multiple representations to communicate their findings or ideas. Science could not advance if scientists were unable to communicate their findings clearly and persuasively. A major practice of science is thus the communication of ideas and the results of inquiry using various modes of representation (National Research Council, 2012). Therefore, if engaging students in practices of science is the proper way for learning physics then developing students' utilization of representations should be a goal of physics education.

Recent researchers in science education argue that to learn science effectively students need to understand the different representations of science concepts and processes, be able to translate a representation into one another, and understand their coordinated use in representing scientific knowledge (Hubber et al., 2010; Prain et al., 2009). The ability to use multiple representations is considered as a key to learning physics (Kohl et al., 2007). Students with higher representation ability have higher chance to solve complex problems successfully (Malone, 2008). Rosengrant et al. (2009) found evidence that students who frequently use multiple representations are successful in force concept inventory (FCI), mechanics baseline test (MBT), and conceptual survey of electrostatics and magnetism (CSEM) tests. Ainsworth (2008) argues that multiple representations play three major functions in learning. First, they play *complementary role* as each representation may differ in the information it expresses or in the processes it supports. Second, they play *constraint interpretations role* in that they help students to understand a difficult representation (because of its complexity or abstractness) using easier representation (because of its familiarity or concreteness). Third, they play *to construct deeper understanding role* that enables students to grasp deeper understanding through integrating information from more than one representation. Ainsworth et al. (2011) claims that engaging students in constructing their own representation will deepen their conceptual understanding and be regarded as the central role of developing expertise. Similarly, Waldrip et al. (2010) argues that unless students can represent their understanding in various modes of representation, their knowledge is unlikely to be sufficiently robust or durable. Therefore, it is critical to provide students of prospective physics teachers with adequate representational skill.

During the last decade, science education researchers in Indonesia have paid attention to develop students' generic science skills (GSS) through leaning science (Ramlawati et al., 2011; Sudarmin, 2011; Wijaya & Ramalis, 2012). GSS is thinking skills and actions closely connected to science as a process and based on the science knowledge (Brotosiswoyo, 2000; Liliasari et al., 2011). GSS includes (1) performing direct and indirect observation, (2) developing sense of scale or magnitude of physical quantity, (3) using symbolic language, (4) self- consistent thinking, (5) employing logical inference, (6) causality thinking, (7) mathematics modeling, and (8) developing concept (Brotosiswoyo, 2000). It is believed that GSS plays as a base to build high order thinking and is transferable to many other situations. Therefore, the prospective physics teachers need to develop the skill as it is useful not only for their further content knowledge growth, but also for teaching the skill to their future students. However, the effort to equip students GSS is still a challenge. Liliasari et al. (2011) argues that it is quite difficult to develop GSS for prospective science teachers. Those reports suggest the necessity of an alternative teaching approach that is different from the more traditionally implemented ones.

Throughout this research, a representational approach in learning physics has been developed and implemented to students of prospective physics teachers. The approach is attributed as representational since the main students' learning activity is to construct multiple representations and use their representations to grasp deep understanding of physics ideas underlying the problem being discussed. Students' learning activities were designed by considering various works on science education research, especially in the area of the use of multiple representations on learning physics, or science in general. These include the works exploring the value of expert-developed representations as well as student-generated representations in learning physics. The later includes the assertion of Waldrip et al. (2010) that unless students can represent their understanding in various modes of representation, their knowledge is unlikely to be sufficiently robust or durable, as well as the assertion of Ainsworth et al. (2011) that engaging students in constructing their own representation will deepen their conceptual understanding and be regarded as the central role of developing expertise. The assertion of Halloun and Hestenes (1985) about the ineffectiveness of conventional-passive student instructions in learning mechanics, the finding of Hake's (1998) survey about the effectiveness of interactive-engagement methods, Heuvelen's (2001) assertion about the importance of multiple exposures for learning new or difficult concepts and skills over an extended time and in variety of contexts, and the work of Ogilvie (2009) and Mullis et al. (2009) about the value of open-ended, multifaceted problem have been utilized as important inputs.

The 'generic outline' of the instruction implemented in this research can be described as follows. (1) The lecturer exposes problem or representational task and asks students to solve the problem using coherent multiple representations. (2) Through a collaborative work in a group, students should solve the problem by constructing representations and critiquing the adequacy, appropriateness, and coherence of their constructed representations. They also need to prepare their best presentation and defending their works on the next whole class discussion. (3) During this group discussion, the lecturer moves around the groups and gives necessary prompts or assistance according to the need of each group. This lecturer's intervention is intended to promote students' GSS and meta-representational skill. For example, (a) if the students have a high degree of certainty about their representations, the lecturer prompts them to justify their reasoning through clarification; (b) if the students are uncertain about their represented claim, or face deadlock in discussion, the lecturer provides them the necessary scaffolds to prompt further reasoning, and (c) if most groups do not have the necessary skill or knowledge to construct appropriate representation, or have no idea to critique the appropriateness of their representation, the lecturer provides the necessary scaffold(s) through class discussion or dialogue. (4) After group discussion, students share their work with others through a whole class discussion. The lecturer facilitates this discussion and provides necessary prompts to improve the students' learning and to consolidate the students' understanding.

As noted earlier, this paper focuses on the impact of the approach on students' generic science skill and representational skill. Accordingly, this paper is intended to address the following research questions: (1) to what extent does the representational approach improve the students' generic science skill?, (2) to what extent does the representational approach improve the students' representational skill?

METHOD

A quasi experiment, one group pretest posttest design has been implemented to address the proposed research questions. The subjects consisted of 24 undergraduate students of physics education program, State University of Malang, taking Selected Topic of the School Physics (STSP) course in Semester I of 2011/2012 academic year.

The main instrument was an integrated test adapted from mechanic baseline test (MBT) (Hestenes & Wells, 1992). The term 'integrated' means that the instrument can be used to assess the students' representational skill and generic science skill simultaneously. For this purpose, the students not only chose one alternative that best represents their response, but also wrote explanation to justify their responses. The student's GSS was measured based on their multiple choices score, whereas the student's representation skill was assessed based on their open explanation in justifying their choice, using rubric presented in Table 1.

Table 1. Rubric to Code the Mode of Students' Representation

Mode	Definition
Verbal (V)	Using sentence to completely express an idea or concept. Words introducing or connecting mathematical, table, graph, or diagram are not included.
Mathematical (M)	Using mathematical equation, doing mathematical manipulation, or using mathematical symbols or numeric in coordinative way. Single mathematical symbols used in a sentence such as "velocity (v) changes with time (t)" are not included.
Table (T)	Using column and raw to represent data, or explicitly refer to available table.
Diagram (D)	Drawing or modifying a diagram or sketch.
Graphical (G)	Drawing or modifying a graph.

There are five GSS components that can be measured using this MBT instrument. They are: sense of scale (SS), using symbolic language (SL), self-consistent thinking (SC), performing logical inference (LI), and causality thinking (CA). Based on the pilot study administered to similar students, this instrument has high reliability, indicated by Cronbach's Alpha value of 0.81.

The students' open explanations to justify their multiple choices response have been coded according to the mode of representation, i.e. whether it is a single representation such as verbal (V), mathematical (M), diagram (D), tabular (T), graphical (G), or their combination (multiple representation). For checking rubric reliability, 25% units of analysis (refering to Hardy et al., 2010) were coded by primary rater (researcher) and one secondary independent rater. The resulted Kappa coefficient agreement was 0.87, indicating high reliability (Everitt & Skrondal, 2010).

RESULTS AND DISCUSSION

Improvement of Students' Generic Science Skills

Student's GSS scores on pretest and posttest are summarized in Table 2. It appears that some data sets (i.e. sense of scale, symbolic language, and causality) are approximately normal, whereas the other two data sets are not normal as they are quite skewed. Therefore, to examine the statistical significance of the difference between posttest and pretest, a paired-sample *t*-test has been employed to the former group and non-parametric Wilcoxon Signed Ranks Test (Leech et al., 2005) for the latter group. Those tests show that the differences between the pair of data sets are statistically significant at $p = 0.000$. This means that the representational approach implemented in this study could improve the students' GSS.

To examine the strength of the improvement, the corresponding *d*-effect size (Ellis, 2010; Morgan et al., 2004) and average N-gain (Hake, 1998) have been calculated for each component. The results are summarized in Table 3. The interpretation of d-effect size is based on the criteria proposed by Morgan et al. (2004), whereas the interpretation of N-gain is based on Hake's refined categorization as follows: low if $\langle g \rangle < 0.25$, lower-medium if $0.25 \leq \langle g \rangle < 0.45$, upper-medium if $0.45 \leq \langle g \rangle < 0.65$, and high $\langle g \rangle \geq 0.65$. From this table, we may conclude that the effect size is in 'much larger than typical' category for all GSS. The average N-gain is in 'high' category for the three skills (self consistence, causality, and logical inference) and in 'medium' category for the other two skills.

Table 2. Students' Pretest, Posttest, and N-gain Scores for Each GSS Component

GSS Component		Statistics							
		Min	Max	Quartile			Mean	SD Mean	Skewness
				First	Second	Third			
Sense of Scale	Pretest	0	75	6.25	25	50	28.1	21.3	0.21
	Posttest	25	100	50	75	94	67.7	26.0	-0.36
	N-Gain	0.00	1.00	0.27	0.59	0.94	0.56	0.35	-0.28
Symbolic Language		0	80	20	40	60	39.2	23.2	-0.28
	Pretest	40	100	40	70	80	68.3	22.8	0.03
		0.00	1.00	0.06	0.45	0.73	0.45	0.37	0.28
Self Consistence		0	75	0	0	50	17.7	25.0	0.94
	Pretest	25	100	75	87.5	100	82.3	21.5	-1.08
		0.00	1.00	0.75	0.88	1.00	0.79	0.27	-1.46
Logical Inference		0	75	25	50	75	47.9	25.4	-0.36
	Pretest	25	100	75	100	100	82.3	22.7	-1.03
		0.00	1.00	0.33	1.00	1.00	0.65	0.42	-0.55
Causality		20	80	40	60	80	58.3	18.6	-0.54
	Pretest	60	100	80	90	100	86.7	15.2	-0.67
		0.00	1.00	0.50	0.84	1.00	0.68	0.38	-0.81

Table 3. Effect Size and Average N-gain for Each GSS Component

GSS Component *)	d-Effect Size		Average N-Gain	
	Value	Category **)	Value	Category
Self-Consistence (SC)	2.88	Very large	0.79	High
Causality (CA)	1.68	Very large	0.68	High
Logical Inference (LI)	1.43	Very large	0.65	High
Sense of Scale (SS)	1.67	Very large	0.56	Upper-medium
Symbolic Language (SL)	1.27	Very large	0.45	Lower-medium

*): Ordered by N-gain
**): Very large means 'much larger than typical

It is useful to examine whether gain scores among GSS components are statistically different. For this purpose, a Friedman test had been implemented as some data sets are not normally distributed. The result is $\chi^2(n = 24,\ df = 4)$ =15.42, p = 0.004. This means that, in overall, those N-gains are significantly different at p = 0.01. To determine which differences between mean ranks are significant, and thus the likely source of the significant Friedman test, the follow up analysis using Wilcoxon test has been employed. The results are summarized in Table 4. The table, shows that only three of the ten possible pairs are significantly different. These are the pairs of SC-SS, SC-SL, and CA-SL. Moreover, N-gain of LI is not significantly different from that of any other components. Based on this statistical analysis, it is clear that N-gain of self-consistence and causality components are significantly higher than that of sense of scale and symbolic language components. This claim is in strong agreement with the value of N-gains shown in Table 3; the average N-gain of SC and CA are in high category, whereas of SS and SL are in medium category.

Table 4. The *p*-Values of Wilcoxon Test for All Possible Pairs of GSS Component

	CA	LI	SS	SL
SC	0.195	0.176	0.001*	0.002*
CA		0.809	0.175	0.027*
LI			0.479	0.074
SS				0.294

*Significant at $p = 0.05$

Efforts to promote generic science skills (GSS) through science courses have been critical issue in Indonesia during the last decade, after Brotosiswoyo (2000) argued the importance for university students to grasp these skills through university physics courses. It is now broadly accepted that these skills need to be developed through science classrooms in all levels of schooling in Indonesia as they are needed for better learning science, transferable to many other situations, and as a base for developing higher order thinking (Liliasari, 2010). However, Liliasari et al. (2011) argue that it is difficult to develop GSS on students of prospective science teachers. This claim confirmes the findings of previous studies, especially on the area of physics education research, such as those by Abdurrahman (2010), Saprudin (2010), and Sutarno (2010). Therefore, it is useful to compare the findings of the present research to those of previous studies.

As previously described, the representational approach implemented in this study significantly improved the students' GSS. More specifically, the improvement on self-consistent and causality thinking skills was so high that the corresponding N-gains were in the category of high gain (0.79 for self consistence and 0.68 for causality). The corresponding results of the previous studies are as follows. First, Abdurrahman (2010), by implementing multiple-representation in teaching quantum physic, improved student's causality and self consistent thinking skills with N-gain of about 0.56 and 0.53 (in average) respectively. Second, Saprudin (2010) and Sutarno (2010), by implementing multimedia interactive, improved causality component with N-gain of 0.37 and 0.58 respectively. They did not assess the improvement of self consistent thinking skill. In addition, the N-gains of other GSS components intervened by those studies were in the category of medium. This comparison indicates that the teaching approach implemented in this research can be considered to be more effective than that implemented in the previous researches, especially in improving self-consistent and causality thinking skills. However, it is useful to review briefly the difference between teaching approach implemented in this present research and that implemented in the previous studies.

Basically, those previous researchers implemented a teaching approach that is similar to that implemented in this present research, but with different strategy. Those researchers used multiple representations as a tool for teaching in which the students learn (or making meaning) from representations provided by lecturer. In another word, they used expert-generated representation strategy. Such teaching strategy is basically based on Mayer's theory of multimedia learning (Mayer, 2005; Mayer & Moreno, 2010) and Ainsworth's (2008) assertion about the values of multiple representations in learning science. On the other hand, the teaching approach implemented in this present study was basically student-generated representation strategy. The students made efforts to construct meaning of science idea, express their idea using their own representation, and negotiate their understanding within and among other students as well as with the lecturer. In other words, the students make meaning of science idea with representation. This comparison suggests that the strategy of making meaning with representations is likely to be more effective than the strategy of making meaning from representations to improve students' GSS.

The high improvement on self-consistent thinking, causality thinking, and logical inference is as expected as the lecturer intensively facilitated the students to develop the skills throughout the lessons. On the problems of kinematics, for instance, the lecturer always asked the students to develop data, construct graphs based on their data, draw the most appropriate mathematical model for their graphs, and draw conclusion about the nature of the motion. When the students had drawn a conclusion about the acceleration of the motion, the lecturer always prompted the students by posing questions such as: '*Is there any net force acting on the ball? If your answer is not, how do you draw the conclusion? Otherwise, if your answer is yes, explain your claim and describe the force that you notice using a range of media including words, diagram, etc.'* To address those challenges, the students not only needed to think self-consistently, but also to employ causality thinking and logical inference. This means that the students had ample opportunities to cultivate the thinking skills over an extended time and in various contexts. According to Heuvelen (2001), the teaching method that provides students such multiple exposures will lead the students to acquire better learning outcomes.

The result of the present research is also in line with the work of Moore and Rubbo (2012). They found that to develop reasoning ability such as hypothetico-deductive reasoning, students need opportunities to construct good 'if ... and ... then ...' statements as much times as possible. The teaching approach that merely focuses on content acquisition does not improve students' reasoning. As stated in advance, the teaching approach implemented in this present study also provided the students with ample opportunities to develop their reasoning skills, including self-consistence, logical inference, and causality thinking.

It is useful to explain why N-gain of using symbolic language is the lowest one (see Table 3). In fact, this approach has paid much attention to the development of this skill. Activities to construct pictorial representation, such as vector representation of velocity and acceleration as well as free force diagram, closely relate to this objective. Such activities almost took place throughout the lessons. However, the N-gain of this skill was the lowest one. This situation can be explained as follows. Some items assessing this skill deal with physics concepts that were not mentioned throughout the lessons, such as the change in momentum due to the collision and the impulse exerted by one object to another during collision. Some students failed to respond to the items correctly. This implies that the nature of generic science skill is content-dependent. It is consistent with the assertion of Brotosiswoyo (2000) and Liliasari et al. (2011).

Improvement of Students' Representational Skill

The kinds of representational mode employed by the students in responding to the pretest and posttest are presented in Tables 5 and 6. From those tables, it is clear that the predominant mode of representation on pretest was single representation (≈55%) consisting of verbal (32%), mathematical (≈18%), and diagram representation (≈5%). In contrast, the most dominant representation mode on posttest was mathematical-diagram (≈20%) followed by verbal-mathematical-diagram (≈18%), and verbal-mathematical (14%). The occurrence of single-verbal representation mode reduced drastically from about 32% on pretest to about 14% on posttest. Table 7 summarizes the changes of representational modes from the pretest to posttest.

Table 5. Students' Representation Modes on Pretest

Category of Representation	Mode of Represen-tation	Total Per Mode		Total Per Category	
		Count	%	Count	%
Single mode	V	169	32.0	289	54.7
	M	96	18.2		
	D	24	4.5		
Multiple, two-mode	VM	50	9.5	161	30.5
	VD	30	5.7		
	VT	1	0.2		
	MD	78	14.8		
	MG	1	0.2		
	MT	1	0.2		
Multiple, three-mode	VMD	8	1.5	8	1.5
Blank	-	70	13.3	70	13.3
SUM		528	100	528	100

Note: V: verbal, M: mathematical, D: diagram or pictorial, G: graphical, T: table

Table 6. Students' Representation Modes on Posttest

Category of Representation	Mode of Represen-tation	Total Per Mode		Total Per Category	
		Count	%	Count	%
Single mode	V	48	9.1	136	25.8
	M	73	13.8		
	D	15	2.8		
Multiple, two-mode	VM	74	14.0	262	49.6
	VD	55			
	VG	3			
	VT	13			
	MD	104			
	MG	7			
	MT	3			
	DG	1			
	TG	2			
Multiple, three-mode	VMD	94	17.8	121	22.9
	VMG	9	1.7		
	VMT	7	1.3		
	VTG	4	0.8		
	MTG	7	1.3		
Multiple, four-mode	VMTG	6	1.1	6	1.1
Blank	-	3	0.6	3	0.6
Sum		528	100	528	100

Table 7. Posttest-Pretest Crosstabulation of the Number Modes of Representation

		Posttest					Total Pre-test	
		NA*	1-mode	2-modes	3-modes	4-modes	Count	%**
Pretest	NA	2	19	35	14	0	70	13.3
	1-mode	1	92	131	61	4	289	54.7
	2-modes	1	25	94	40	2	161	30.5
	3-modes	1	0	2	6	0	8	1.5
Total Post-test	Count	3	136	262	121	6	528	100
	%[b)]	0.6	25.8	49.6	22.9	1.1	100	

* NA: no representation (the answer sheet is blank)
** Relative to total of reasoning units (528)

Chi-square test implemented to cross-tabulation (Table 7) showes that the students' representation on posttest was significantly different from that of pretest (χ^2 = 36.47, df = 12, p = 0.000). Table 7 shows that 196 of 289 (about 67%) single-representation modes changed to multiple-representations mode, whereas only 25 of 169 (about 16%) multiple-representations modes changed to single-representation mode. this suggests that students have improved their use of multiple representations in solving physics problems.

It is useful to compare the students' representations with expert's representation in solving the same problem. Figure 1 shows this comparison. The students' representation on pretest was quite different from expert's representation (χ^2 = 470.1) while that on posttest was very close (χ^2 = 14.3), even though it was statistically different (the critical value of Chi--square with df = 2 and α = 0.05 is 5.99). This suggests that the approach could improve the students' representational skill as close as the expert's.

This finding corroborates many previous studies showing that experts and novices differ in the use of representation in problem solving. Novices tend to jump directly to mathematics, while experts tend to use multiple representations (Kohl et al., 2007; Kozma & Russell, 2005). This present study shows that students tended to use single representation (mostly verbal or mathematical) before instruction, in which most students were at under competent level in mechanics (see Sutopo et al. (2012) for the improvement of students' competence on mechanics). In contrast, after instruction, in which most students were at competent or mastery level, they tended to use multiple representations in responding to the same test. It can be argued that the teaching approach implemented in this study could improve the students' problem solving procedure as close as that of experts.

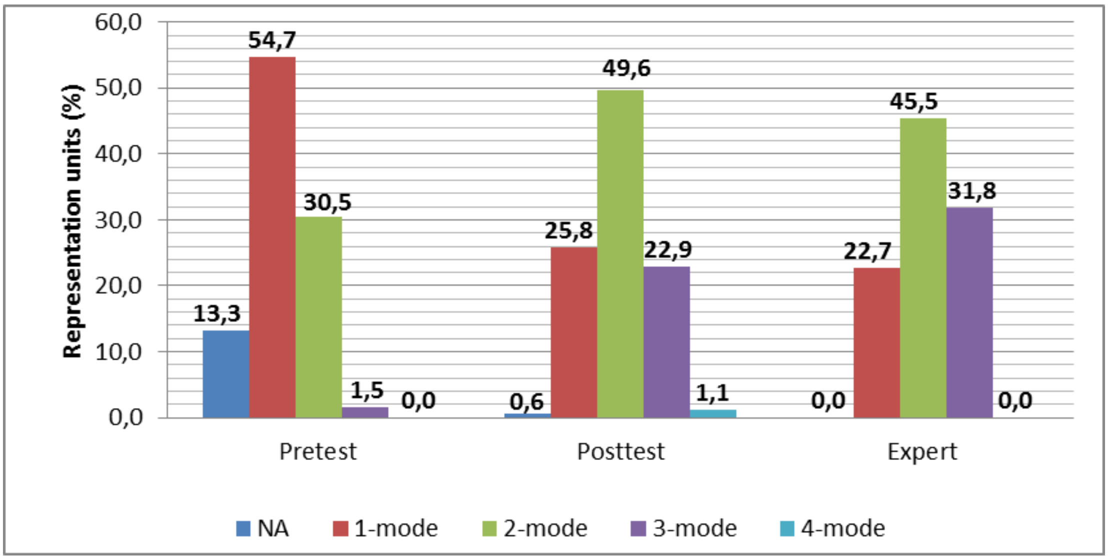

Figure 1. The Comparison of Representation Modes Performed by Students (Pretest and Posttest) and an Expert
(NA: not available due to the students' answer sheet blank)

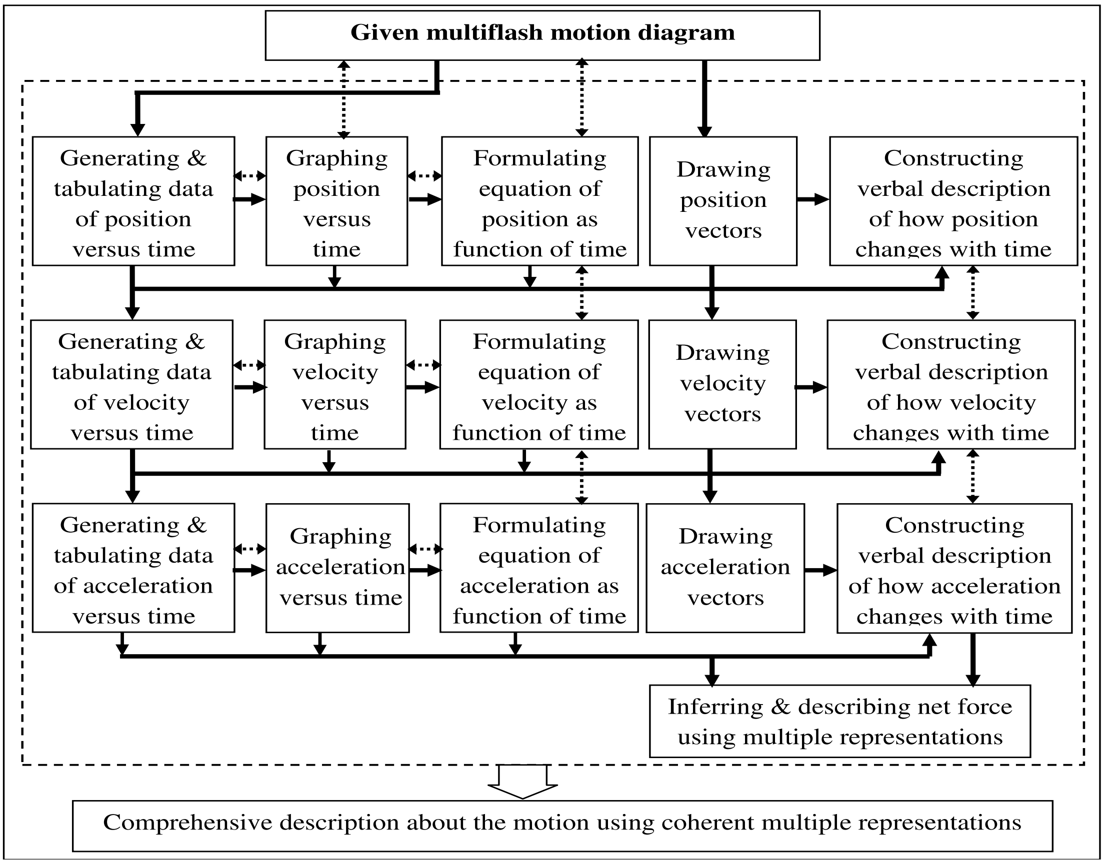

Figure 2. Students' Learning Activities
(Solid arrows indicate working or thinking sequence, two-headed dashed arrows indicate activity to check the consistency among the resulted representations)

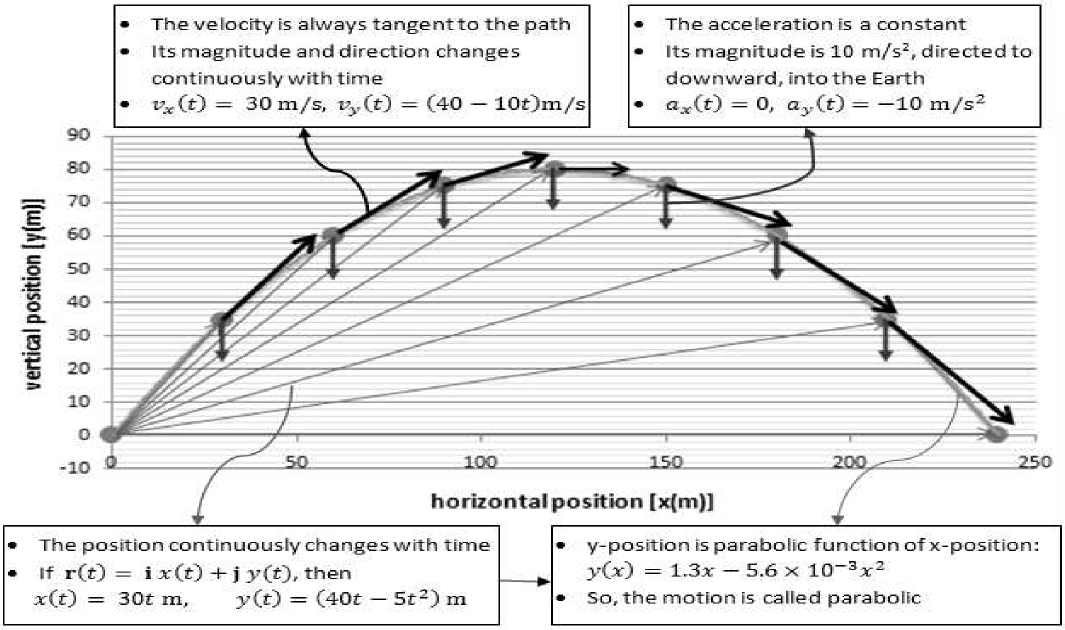

Figure 3. Example of Students' Multiple Representations (Verbal, Diagram, and Equation) about Parabolic Motion, Including Position, Velocity, and Acceleration
(Mathematics equations were formulated based on the tables and graphs that students have developed in advance)

The high improvement of the students' representational skill is as expected as students' learning was very rich with the construction of coherent multiple representations (see Figure 2). This means that the students had ample opportunities to improve their representational skill throughout the lessons. Therefore, this finding confirms Heuvelen's (2001) claim that a teaching approach that provides students with multiple exposures about a skill or knowledge will lead students to grasp the skill or knowledge thoroughly. This result also corroborates the finding of Kohl and Finkelstein (2006) that the pervasiveness of multiple representations use in physics instruction plays a significant role in developing students' representational skills.

In addition, throughout the lessons, the lecturer consistently gave the students supports and time to construct coherent multiple representations as best as they could do. According to diSessa (2004), such teaching strategy enables students to productively construct representations, even approaching qualities of expert-generated representation in terms of precision, conciseness, and completeness. This study corroborates this assertion. Figure 3 presents an example of typical multiple representations constructed by students in describing parabolic motion. This student-generated representation is quite precise (clear or unambiguous), concise (give minimal but sufficient information), and complete (comprehensive for its purpose).

The students' success in performing better representation on posttest indicated that they have been through meaningful learning experiences that enable them to apply their knowledge and skills to new context (Mayer & Moreno, 2010). This finding also corroborates the claim of Waldrip et al. (2012) that through the construction of representations, students can develop problem-solving skills that could be applied in new contexts. They claimed that in making their own representations, students focus on the key aspects of the problem, select the appropriate tools, and apply the relevant background knowledge.

CONCLUSION

Based on the findings and discussion, it can be concluded that representational approach implemented in this study was effective to improve the students' generic science skill and representational skill. The students' generic science skills that include self-consistent thinking, causality thinking, logical inference, sense of scale, and using symbolic language were improved with very high effect size for all skills and with N-gain that is in high category for the first three skills, upper-medium category for the fourth, and lower-medium category for the last. Students' representational skill jumped from 'quite different from' to 'very close to' expert's representation.

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