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Analysis of Students Use of Multimodal Representations in a Science Formative Assessment (Assessing Pupils' Progress, APP) Task in the UK

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ABSTRACT. The purpose of this study was to examine UK students' use of multimodal representations in science. Students were asked to explain their understandings of the scientific concept and presentation of the multimodal representations in a science Assessing Pupils' Progress (APP) task. Participants of this study were fifty-four Year 7 students taught by the same teacher. Students from one class (27 students) were assigned to the experimental group, and then they received instruction encouraging the using of multimodal representations as evidences to support students' claims. One class (27 students) was assigned to the control group and they received instruction with traditional teaching methods. Both groups performed an APP task for assessment. The samples of APP assessments produced by students both from the experimental and control groups were analyzed using an analysis framework of multimodal representations, embeddedness in evidence and understanding of scientific concepts. Data analysis indicated that the students in the experimental group performed better than that of the control group on embeddedness of multimodal representations in the APP task. In addition, there was a significant difference between the two groups in the evaluation of understand of the scientific concepts.

Key words: Multimodal representations, APP (Assessing Pupils' Progress), Assessment

INTRODUCTION

There has been an instruction paradigm shift; student-centered instructional approach places the students in the center of the learning process.[1,2] Students have opportunities to learn independently and from others through discovery of knowledge.[3] This strategy can increase motivation to learn, greater retention of knowledge, and deeper understanding.[4] Learners themselves reconstruct the scientific knowledge actively and generate new knowledge.[5,6] Social constructivism, a powerful force driving today's education, sustains that learning was the process by learners were integrated into a knowledge community using language.[7]

Language in the process of learning science is an important part in organizing scientific knowledge and ideas and making claims.[8,9] In science, learning through language is composed of two parts: speaking and writing. Speaking includes not only verbal interaction as text writing or presentation,[10] but also epistemic activities that can help make scientific thinking and reasoning visible.[11] Science learning through writing is one way of learning to acquire concepts and compose knowledge based on scientific evidence away from the traditional science lecture approaches.[12] Students can persuade others of the validity of their claims by using language of science through writing.[13,14]

One way to extend this notion of writing-to-learning science is to encourage students to use multiple modes of representation. Enactive writing as the cognition and transformation of ideas involves the representation of ideas in visual form as well as in verbal form.[15] Learning through speaking refers to the process whereby students engage in justification of claims to knowledge based on multimodal representations in the scientific evidence.[16] Students will refine visual information and clarify the meaning through the writing by using multimodal representations clearly.[17] Multimodal representations are pervasive in science literature and communication. These are the texts, figures, diagrams, tables, pictures, graphs and mathematical equations.[18,19]

In this study, students use multimodal representations actively to present evidences which have a logical connection with their claims.[19,20] The use of multimodal representations could play an important role in helping students construct a deeper understanding and learning of science concepts.[21,22] At this point, the given evidence should be appeared as a variety of multimodal representations. Students present multiple representations with their explanation in the APP task after science lesson and use their claims and evidence through multiple representations. APP assessment is a periodic review giving a clear profile of students' achievement across a whole subject, which informs and shapes future planning and targets for improvement. With this respect, we investigated effects of encouraging multimodal representations as evidences to support students' claims in a science Assessing Pupils' Progress (APP) assessment at secondary schools.

Research Question

The research questions guiding this study are the following:

(a) What are the impacts of multimodal representations instruction on the use of multimodal representations in science APP task?

(b) What are the impacts of multimodal representations instruction on students' understanding of scientific concept?

THEORETICAL BACKGROUND

Assessing Pupils' Progress (APP) task

APP is the government's Assessment for Learning Strategy[23] and overseen by the Qualifications and Curriculum Authority (QCA) and Department for Children, Schools and Families). The DSCF claimed that the use of APP would promote Assessment for Learning (AfL) and lead to improvements in teachers' curriculum planning and through this a raising of standards. APP in key stage 3 science was introduced in January 2009 in the UK. According to Rowe (2010),[24] the APP approach particularly supports periodic assessment, when teachers sum up progress over the medium term and adjust their curriculum planning. It also aims to provide support for day-to-day assessment and at transitional points between year groups, schools and phases. APP should be based on a wide range of evidence, be personalized and integrated into teaching and learning, and should yield both formative and summative information which feeds into curriculum planning and personalized learning. APP aimed to provide a better balance between content and scientific processes. APP is assessment for students undertaken by teachers and provides information to be used as feedback to modify the teaching activity and teachers' planning. APP uses pupils' day-to-day work that is already in pupils' exercise books, portfolios and presentations on which some of their spoken contributions in class.[23] In this study, we consider that APP task gives students an opportunity to explain what they understand, after each module was finished. Therefore, APP task was one of the ways in which multimodal representations used by the students.

Multimodal Representations

Multimodal representations are defined as various modes of language and forms in order to present and represent science data, ideas, knowledge and concepts and support a variety of learning activities, cognitive processes and deeper understanding of the science.[21]

Referring to three modes, Gilbert (2004)[25] defines, 'verbal mode' as the reality and relationship with realities in writing that students use, 'symbolic mode' as made up by chemical symbols, chemical formulas, and mathematical expressions, and 'visual mode' as graphic, graphs and pictures. Our work in relation to multimodal representations has been refined through experiences in the science classroom of one of the researchers. In this study, the multimodal representations appearing in the pupils' presentations of APP task are classified into three modes as mentioned above.

METHODS OF STUDY

Participants of Study

The study was conducted in the Year 7 of coeducational and catchment school located in Nottingham, in the UK. Students' age range in the school was 11-18 and student roll numbers was 1359. The school had been converted from Foundation School to Academy at Aug. 31, 2010. This academy school was independent, nonselective, state-funded schools that fall outside the control of local authorities, and were managed by a private team of independent co-sponsors. The curriculum in this school was decided without recommendation of government. Most of schools of the UK were KS3 consists of Year 7, 8 and 9. Instead, Year 7 and 8 belonged to KS3 in this school and Year 9 starts GCSE curriculum.

The participants were 54 Year 7 students. The experimental group consisted of one class of 27 students and the control group consisted of another class of 27 students. The experimental group received instruction encouraging using multimodal representations as evidences to support claims. On the other hand, the control group received instruction without encouraging multimodal representations. Students in two groups learned the same topic and the same content on the same module in Year 7 science course.

The teacher participating in this study had five years of teaching experience at the secondary level and majoring in biology. She taught both the experimental group and control group.

The authors developed the instruction encouraging multimodal representations based on prior research[26] and one of the authors participated in this study. She explained details of the research and the lesson to the teacher. She acted as an assistant teacher of two groups to answer fairly to the questions of the students and helped students prepare for presentation without mentioning about multimodal representations. She had 10 years of teaching experience majoring in chemical engineering and chemistry education.

She was placed at the local school in the UK by 'Overseas Expansion Program of Excelling Teachers' for one year. She was involved in instruction encouraging multimodal representations as an assistant teacher.

Encouraging Multimodal Representations

Science modules of Year 7 consisted of 10 topics of module for three semesters in chemistry, physics and biology subjects. Topics and contents of science modules in the experimental and the control groups were shown in *Table* 1.

***Table* 1.** Topics and contents of science modules of Year 7

Related subject	Topics of modules	Contents of modules
Chemistry	It's elementary	Elements, compounds and mixtures Patterns of behavior
Physics	Scaredy cat	How are sounds made Hearing and ranges Use of sound
Physics	Motorcycle safety	Forces and Motorcycles Investigating friction Unbalanced forces Balanced forces High speed smash
Chemistry	Garden indicator	Dip and check Hazard labels Acid and alkali Acid and metal Acid and base Indicators
Biology	Disgusting digestion	Organs and systems Circulatory system A varied diet Digestive system Adaptations of digestive system
Chemistry	Mars rocks	Types of rock Igneous Sedimentary and metamorphic Weathering and erosion Rock cycle
Physics	Twist and shout	Simple machines Levers Moments Balanced and unbalanced
Biology	**Life story**	Puberty and menstrual cycle **Sexual reproduction** Stages of fetal development Gestation periods Ideas about reproduction
Biology	Cell out	Microscopes Animal cells Plant cells Specialized cells Tissue and organs Organ systems
Biology	Monkeying around	Behave or react Yawning and dribbling Woodlice Behavior for survival

The topic selected for this study was 'Life story' in biology subject and also chose 'Sexual reproduction' content among five contents. The lessons were composed of four periods having 60 minutes for each period. During the first and second periods of the lessons, students of both groups learned the same contents as flower dissection and pollination. At the third period of the lessons, both group of students planned and prepared for APP task. They were divided into small groups of two to five persons. The group discussion took place in terms of how to discuss and organize their explanations and share their ideas. The last period of the lessons, students of both groups made their own presentation as APP task to whole class.

Lesson plans for the experimental and the control groups were shown as *Table* 2. The instruction of the experimental group designed to encourage the use of multimodal representations. Experimental group students started with explanation using a variety of representations as evidence to support their claims. Then they were asked to recall an importance of evidences and multimodal representations to persuade other people at the third period of the lessons. The instruction was to encourage the students to discuss how multimodal representations were used and whether these representations were useful in helping others understanding the ideas presented in their presentations.

Implementation of APP task

APP task supported periodic assessment at the end of the lessons. During this assessment, students in both groups participated in a small group discussion and whole class presentations.

The intent of APP task was to encourage the students to discuss how scientific concepts were expressed and whether these were useful in helping them understand the ideas presented in their presentations. During planning and preparing for APP task, the students of both groups have an opportunity of discussion in a group. APP task was asked to produce

***Table* 2.** Lesson plans of the experimental and control groups

Period	Experimental group	Control group
1st	Flower dissection + Representations	Flower dissection
2nd	Pollination	
3rd	Planning and Preparing + Representations	Planning and Preparing
4th	Presentation [APP task]	

students own explanation and present to the whole class. Students constructed a model or leaflet, created a PowerPoint, drew pictures, wrote scripts and practiced a role-play for their presentations. These presentations should reflect on students' understanding and how sharing their ideas help students understand science concepts. They were video-recorded and collected by author, and then transcribed for analysis.

Cognitive Abilities Test (CAT)

CAT was an assessment of a range of reasoning skills. CAT was sets of tests which assess a student's ability to reason with and manipulate the three different types of symbols that played a substantial role in human thinking: words, numbers and shapes or figures, i.e. verbal, quantitative and non-verbal reasoning as thinking with shape and space.[27] CAT scores were utilized in order to acquire the students who were progressed form primary school. The scores indicate general transferable abilities, such as the ability to recognize similarities, analogies, patterns and relationships, all fundamental to understanding and using new information. They were designed to minimize the role of prior learning and could therefore provide an indication of potential.

Students who were score higher than above average 127+ was the 'Very high' category of CAT scores as shown *Table* 3. CAT test was conducted at the beginning of the new academic year for experimental and control group.

Module Test

Module Tests were conducted after the lessons of each module as written test for judgments of academic achievement of experimental and control group. In this study we used test results of 2 modules before implementing target module for the study.

Analysis of Multimodal Representations

In the APP task, students were asked to explain to their friends what they understood about the topic given. Experimental and control group students completed this presentation task in the last period of the lessons. The APP task was scored using an analysis framework of multimodal representations. The analytical framework focused on two aspects of student's presentation; an assessment of the use of multimodal representations and an assessment of embeddedness of multimodal representations.

Table **3.** Cognitive Abilities Test (CAT) scores

CAT score	Rate	% of students nationally	Description
127+(max 141)	9	4	Very high
119-126	8	7	Above average
112-118	7	12	Above average
104-111	6	17	Average
97-103	5	20	Average
89-96	4	17	Average
82-88	3	12	Below average
74-81	2	7	Below average
73-	1	4	Very low

Firstly, the assessment rubric focused on using modes of representations, such as verbal mode, symbolic mode, and visual mode. Verbal mode was representation for transferring concepts and ideas from evidence to support students' claims.[26,28] Mode was composed causal relationship, enumeration and experience of everyday life related to scientific phenomenon. Symbolic mode was the ability for the conceptual understanding in chemistry. There were the chemical symbols, unit of dimension and mathematical formulas and in sub-modes of symbolic mode. Visual mode was made_explicit information and knowledge.[28] Mode consisted of picture and graph. 'Picture' aroused students' interest,[29,30] and brought positive relationship between problem-solving skills and students' visual representation.[31–33] 'Graph' was visual displays that depict the relationships between continuous variables in pictorial forms.[34] One point was added according to the frequency appeared in each sub-mode of multimodal representations, and the sum of each sub-mode score was the score of the three mode.

Secondly, the embeddedness of multimodal representations was accurately and coherently use of the representations in the context of the student to communicate with others. It meant the qualitative analysis of multimodal representations. It consisted of integration, accuracy of claim and/or evidence and emphasis. Integration was linking among the different modes representing science information.[26,35] Adequacy was a logical relationship between the representation as evidence and the claims. The prerequisite for adequacy was made up of the correct scientific concepts.[26] Emphasis was the way to help others understanding such as captions for figure and grape, placed next to the text and referred to the next with the associated visual mode, and key terms underlined or highlighted.[26,35]

Analysis of Understanding of Scientific Concept

The analytical framework of understanding of scientific concept was developed for this study based on the analysis framework which Nam *et al*. (2008)[36] developed. Understanding of scientific concept consisted of two parts: big idea and describing scientific concepts.

Big idea meant fundamental elements of scientific concepts. There were two big ideas of this particular plant les-

***Table* 4.** Framework of understanding of scientific concept

Elements			Frequency	Score
Big idea	Flower parts (Dissection)	To distinguish the female and male parts.		
		To accurately name each part.		
	Pollination	To know the process for pollination.		
		To know different ways of pollination.		
Describing scientific concepts	Accuracy of scientific concepts			
	Text characteristics match intended writing type			
	Language appropriate for audience			

***Table* 5.** Homogeneity of the groups

	Group	N	Mean	SD	p
CAT scores	Experimental group	27	105.17	11.76	0.770
	Control group	27	104.96	10.49	
Module test scores	Experimental group	27	69.22	17.43	0.626
	Control group	27	67.48	11.52	

son. Describing scientific concepts included accuracy of scientific concepts, text characteristics match intended writing type and language appreciate for audience (*Table* 4).

Data were analyzed using SPSS 18.0. CAT score, Average APP level and Module Test percent were tested for homogeneity of the experimental group compared with the control group using independent t-tests. Differences for encouraging multimodal representations were examined for all students of both groups using a t-test.

RESULTS

The research aims to investigate effects of encouraging multimodal representations as evidences to support students' claims in a science APP assessment at secondary schools in the UK. We compared CAT test scores and Module Test scores as a homogeneity test before implementing the instruction encouraging use of multimodal representations. The control group students scored higher than the experimental group, but there was no statistically significant difference (*Table* 5). These results indicated that there was no significant difference in students' learning ability between the groups.

Mode Analysis of Multimodal Representations in the Science APP Task

There was no significant difference in the mode of multimodal representations between the experimental group and the control group ($p <.05$). In the two sub-modes of multimodal representations such as verbal and visual mode, we confronted with data showing no statistically significant difference between two groups. The symbolic mode was not shown at all in the experimental group and the control group (*Table* 6).

Embeddedness Analysis of Multimodal Representations in the Science APP Task

There was a significant difference in the embeddedness of multimodal representations between the experimental group and the control group ($p <.05$). In an accuracy of claims and evidence as a sub-element of embeddedness,

***Table* 6.** Mode analysis of multimodal representations in a science APP task

Elements	Group	N	Mean	SD	t	p
Verbal mode	Experimental group	27	1.20	1.14	0.177	0.905
	Control group	27	1.11	1.05		
Symbol mode	Experimental group	27	0.00	0.00	-	-
	Control group	27	0.00	0.00		
Visual mode	Experimental group	27	3.00	0.82	0.440	0.798
	Control group	27	3.22	1.30		
Total	Experimental group	27	4.20	1.62	0.156	0.900
	Control group	27	4.33	2.06		

***Table* 7.** Embeddedness analysis of multimodal representations in a science APP task

Elements	Group	N	Mean	SD	t	p
Integration	Experimental group	27	1.90	0.57	1.37	0.193
	Control group	27	1.56	0.53		
Accuracy	Experimental group	27	2.50	0.53	2.89	0.015*
	Control group	27	1.67	0.71		
Emphasis	Experimental group	27	5.60	2.17	1.62	0.108
	Control group	27	3.89	2.42		
Total	Experimental group	27	10.00	3.02	2.04	0.044*
	Control group	27	7.11	3.14		

*p<.05

***Table* 8.** Analysis of understanding of scientific concepts in a science APP task

Elements	Group	N	Mean	SD	t	p
Big idea	Experimental group	27	9.00	2.21	2.23	0.046*
	Control group	27	6.67	2.35		
Describing of scientific concepts	Experimental group	27	2.60	0.52	4.36	0.002*
	Control group	27	1.56	0.53		
Total	Experimental group	27	11.60	2.63	2.74	0.023*
	Control group	27	8.22	2.73		

*p<.05

the experimental group gained significantly higher than the control group ($p<.05$). In integration and emphasis in the sub-element of embeddedness, the experimental group was higher than the control group, but no significant difference (*Table* 7).

The results indicated that students involved in the multimodal representation instruction were significantly better in embeddedness of multimodal representations.

Analysis of Understanding of Scientific Concepts in the Science APP Task

There was a significant difference in understanding of scientific concepts in a science APP task between the experimental group and the control group ($p<.05$). All sub-elements of understanding of scientific concepts in the experimental group was significantly higher than the control group ($p<.05$) (*Table* 8). From these results, the multimodal representations encouraging lessons had an effect on students' understanding of scientific concepts. Students organized their ideas by using a scientific language.

CONCLUSION AND IMPLICATIONS

The purpose of this study was to investigate effects of encouraging multimodal representations as evidences to support students' claims in a science APP assessment at secondary schools in the UK.

Results from our study showed that students in the experimental group spontaneously utilized a broader representational emphasis with a much higher use of integration, accuracy and emphasis of representing information through presentation in science APP task. Results indicated that students in lessons of encouraging multimodal representations expressed better scientific concepts. Also their presentations were not simply listed scientific concepts, but rather showed concepts through a big idea.

This instruction suggested how to use modes of representations to appropriately and effectively understand and communicate about science concepts. The multimodal representations encouraging lessons also affected on students' understanding of scientific concepts through organizing their own explanation by using a scientific language.

When students effectively embed multiple modes of representations, they are more likely to engage in a beneficial cognitive process in which they more deeply and accurately assess their own understanding of the concept before they determine how to represent best science concept to other student.

In the future, we need to continue research on the multimodal representations as scientific language and design teaching strategy for improving embeddedness of multimodal representations as evidences.

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REFERENCES

1. Barr, R. B.; Tagg, J. *Change: The Magazine of Higher Learning* **1995**, *27*, 12.
2. American Association for the Advancement of Science. Washington DC: National Academy Press, 1993.
3. Huba, M. E.; Freed, J. E. Needham Heights, MA: Allyn & Bacon, 2000.
4. Collins, J. W.; O'Brien, N. P. Westport, CT: Greenwood, 2003.
5. Kwon, Y. J.; Jeong, J. S.; Park, Y. B.; Kang, M. J. *Journal of the Korean Association for Science Education* **2003**, *23*, 215.
6. National Research Council. National Academy Press: Washington, DC, 2000.
7. Vygotsky, L. S. Cambridge Mass; Harvard University Press: 1978.
8. Ash, D. *Journal of Research in Science Teaching* **2008**, *45*, 1.
9. Yore, L. D.; Florence, M. K.; Pearson, T. W.; Weaver, A. J. *International Journal of Science Education* **2006**, *28*, 109.
10. Dillon, J. T. Open University Press: Buckingham, 1994.
11. Duschl, R. A. Ellenborgen, K. Paper presented at the International Conference on Literacy; Empowering and Informing Instruction: Victoria, BC, Canada, 2002.
12. Kelly, G. J.; Bazerman, C.; Skukauakaite, A.; Prothero, W. Paper presented at the International Conference on Ontological, Epistemological, Linguistic and Pedagogical Considerations of Language and Science literacy; Empowering Research and Informing Instruction: Victoria, BC, Canada, 2002.
13. Duschl, R.; Ellenbogan, K.; Erduran, S. A paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, 1999.
14. De Vries, E.; Lund, K.; Baker, M. *Journal of the Learning Sciences* **2002**, *11*, 63.
15. Emig, J. *College Composition and Communication* **1977**, *28*, 122.
16. Erduran, S.; Jimenez-Aleixandre, M. P. Dordrecht, The Netherlands: Springer, 2008.
17. Hand, B.; Wallace, C.; Yang, E. *International Journal of Science Education* **2004**, *26*, 131.
18. Schnotz, W.; Lowe, R. *Learning and Instruction* **2003**, *13*, 117.
19. Bennett, W. D. Doctoral dissertation, The University of Iowa, 2011.
20. Kelly, G. J.; Takao, A. *Science Education* **2002**, *86*, 314.
21. Ainsworth, S. E. *Computers & Education* **1999**, *33*, 131.
22. Nakhleh, M. B.; Posteck, B. Netherlands: Springer, 2008.
23. Department for Children, Schools and Families (DCSF) London: DCSF, 2008.
24. Rowe N. National Foundation for Educational Research, 2010.
25. Gillbert, J. *International Journal of Science and Mathematics Education* **2004**, *2*, 115.
26. Cho, H. S. Master dissertation, Pusan National University, 2009.
27. McClure, L.; Piggott, J. Routledge, 2007
28. Dori, Y. J.; Sasson, I. *Journal of Research in Science Teaching* **2008**, *45*, 219.
29. Glynn, S. *The Science Teacher* **1997**, *64*, 30.
30. Stein, M.; McNair, S.; Butcher, J. *Science and Children*, **2001**, *38*, 18.
31. Bonder, G. M.; McMillen, T. L. B. *Journal of Research in Science Teaching* **1986**, *23*, 727.
32. Carter, C. S.; LaRussa, M. A.; Bo Bonder, G. M.; McMillen, T. L. B. *Journal of Research in Science Teaching* **1986**, *23*, 727.
33. Staver, J. R.; Jacks. T. *Journal of Research in Science Teaching*, **1988**, *25*, 763.
34. McKenzie, D.; Padilla, M. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, 1984.
35. Bogiages, C. Doctoral dissertation, University of South Carolina–Columbia, 2014.
36. Nam J. H.; Kwak K. H.; Jang, K. H.; Hand, B. *Journal of the Korean Association of Science Education* **2008**, *28*, 922.