

# EUROPEAN JOURNAL OF STEM EDUCATION

Volume 1, Issue 2  
2016

**Editor-in-Chief**

**Hanno van Keulen**

Windesheim University of Applied Sciences (The Netherlands)

e-ISSN: 2468-4368

JOURNALS  
**lectito**

*This page intentionally left blank.*

## EDITORIAL BOARD



### Editor-in-Chief

**Hanno van Keulen**

Windesheim University of Applied Sciences (The Netherlands)  
[h.van.keulen@windesheimflevoland.nl](mailto:h.van.keulen@windesheimflevoland.nl)

### Managing Editor

**Masha Rademaker**, Lectito Publishing (The Netherlands)

### Editorial Board

**Amauri Bartoszeck**, Department of Physiology & Neuroscience and Emergent Science Education, University of Paraná (Brazil)

**Andreas Dress**, Faculty of Mathematics, University of Bielefeld (Germany)

**Annette Gough**, School of Education, RMIT University (Australia)

**Antonio Quesada**, Department of Science Education, University of Jaén, (Spain)

**Azra Moeed**, Science Education, Faculty of Education, Victoria University of Wellington (New Zealand)

**Cathy Bunting**, Faculty of Education, The University of Waikato, (New Zealand)

**Christine Harrison**, Department of Education, King's College (UK)

**Cristina Almeida Aguiar**, Department of Biology, Escola de Ciências, University of Minho (Portugal)

**Erin E. Peters-Burton**, Science Education and Educational Psychology, College of Education and Human Development, George Mason University (USA)

**Evangelia Mavrikaki**, Faculty of Primary Education, National and Kapodistrian University of Athens (Greece)

**Gilmor Keshet**, School of Education, The Hebrew University of Jerusalem (Israel)

**Ileana M. Greca**, Departamento de Didacticas Especificas, Universidad de Burgos, (Spain)

**Jogymol K. Alex**, Department of Mathematics and Science Education, Walter Sisulu University (South Africa)

**Joseph Jabulane Dhlamini**, College of Education, University of South Africa (UNISA), (South Africa)

**Laszlo Egyed**, University of Kaposvar, (Hungary)

**Liz Lakin**, School of Social Sciences, University of Dundee (UK)

**Maria Eduarda Ferreira**, Polytechnic institute of Guarda, (Portugal)

**Maria Evagorou**, Department of Education, University of Nicosia (Cyprus)

**Martin Bilek**, University of Hradec Kralove, (Czech Republic)

**Mohd Salleh Abu**, Faculty of Education, Universiti Teknologi Malaysia, (Malaysia)

**Pavol Prokop**, Department of Biology, Faculty of Education, Trnava University, (Slovakia)

**Remalyn Quinay Casem**, Don Mariano Marcos Memorial State University, (Philippines)

**Reuven Babai**, Department of Mathematics, Science and Technology Education, Tel Aviv University, (Israel)

**Rohaida Mohd. Saat**, Department of Mathematics and Science Education, University of Malaya (Malaysia)

**Silvija Markic**, Institute for the Didactics of the Sciences (IDN) - Chemistry Education, University of Bremen (Germany)

*This page intentionally left blank.*

**VOLUME 1 ISSUE 2, 2016**

**TABLE OF CONTENTS**

**Research Articles**

- 1 **Effects of flipped instruction on the performance and attitude of high school students in mathematics**  
Remalyn Q. Casem  
<https://doi.org/10.20897/lectito.201620>
- 2 **Learning the language of earth science: Middle school students' explorations of rocks and minerals**  
Angelia Reid-Griffin  
<https://doi.org/10.20897/lectito.201621>



<http://www.lectitopublishing.nl>



<https://www.facebook.com/LectitoJournals/>



<https://twitter.com/lectito1>



<https://www.linkedin.com/in/lectito-journals-9a675010b/>

# Effects of flipped instruction on the performance and attitude of high school students in mathematics

Remalyn Q. Casem<sup>1\*</sup>

<sup>1</sup>*Don Mariano Marcos Memorial State University, PHILIPPINES*

Published: March 25, 2016

## ABSTRACT

This study aimed to determine the effects of flipped instruction on the performance and attitude of high school students in Mathematics. The study made use of the true experimental design, specifically the pretest-posttest control group design. There were two instruments used to gather data, the pretest-posttest which was subjected to validity and reliability tests and the Modified Fennema-Sherman Attitudes Scale. It was found out that the experimental and control groups were comparable in the pretest and posttest. Comparison on their gain scores revealed significant difference with performance of the experimental group higher than the control group. There was no significant difference on the level of attitude of the participants in the experimental group before and after the study in terms of confidence in learning mathematics, attitude toward success in mathematics, mathematics anxiety and perception of teacher's attitudes. A very weak positive relationship existed between performance and attitudes toward mathematics.

## Keywords

inverted classroom,  
flipped instruction,  
mathematics performance,  
attitude towards  
mathematics

Received: 5 Jan 2016

Revised: 22 Feb 2016

Accepted: 4 Mar 2016

DOI: 10.20897/lectito.201620

## BACKGROUND/ OBJECTIVES AND GOALS

The main objective of teaching is learning. This is why teachers are continually trying out effective approaches that will work for particular subjects. A typical classroom allocates time in a way familiar to anyone: students gather during class sessions to hear lectures from a teacher and take down notes, and then students work on homework and projects outside of class. This traditional classroom setup is not best for learning. Students are expected to be inside the classroom with maximum teacher's supervision when they need the least help and they are faced with easier cognitive activities. The more difficult tasks given to students are usually done outside the classroom on their own without the help of the teacher or their peers. Inverting the setup of the classroom seems to be an improvement: students acquire fundamental concepts and basic learning competencies through readings, video lectures and other sources outside the classroom, and then put them to work on high-level cognitive tasks inside the classroom (Talbert 2012). In this way, students do challenging tasks inside the classroom where teacher's help is much needed and easily be extended to them. The inverted classroom promises conforms to the way students learn today in this digital world. It promises a more engaging and effective instruction process. In fact, students became engaged in the material more regularly than before inverting the classroom setup and had shown enthusiasm in classroom discussion (Gaughan 2014).

In a traditional classroom, instruction is primarily given inside the classroom in a 60-to-90-minute time allotment where students learn the basics of the lesson and are sent home with a great deal of similar tasks given inside the classroom but with increased level of difficulty. Conversely, in an inverted classroom, the

\*Correspondence to: rhemz\_vhinz@yahoo.com

setup is exactly opposite. Flipped instruction is an approach applied in an inverted classroom. Flipped is a specialized term for the general term blended (Margulieux et al. 2014). Flipped instruction employs interactive learning tasks inside the classroom, and direct individual instruction outside the classroom. In this approach, the content is delivered as homework through video tutorials, online interactive activities or reading assignments. Prior instruction is given outside the classroom through varied sources meticulously prepared or collated by the teacher to the students for them to learn the basics on their own, in lieu of letting the teacher lecturing in class. The classroom then becomes the place to work through problems, advance concepts, and to engage in collaborative learning. The 60-to-90-minute class time is used to further students' learning. Flipped instruction makes students get actively involved and cognitively awakened. It makes teachers easily query individual students, check out for misconceptions on some concepts, and clarify incorrect notions. With this approach, there is an individualize learning for all students, which will certainly increase their achievement and interest level. Students are learning with control of time, place and pace. Students learn best when they are in an environment that gives them the opportunity to feel competence, relatedness, and autonomy (Deci & Ryan 2000).

Educators want to break the traditional lecture-oriented instructional model by focusing on student learning needs and capitalizing their potentials. Flipped instruction can enable teachers to shift from teacher-driven to student-centered learning. This shift unveils one characteristic in an outcomes-based education where students are responsible for their own learning and the teacher acting as guide-on-the-side. Flipped instruction also addresses the development of media and technology skill, a 21st century skill the K-to-12 curriculum promises to cultivate among basic education students.

Moreover, according to Peter Pappas, an international trainer on the improvement of the quality of teaching and learning, in a webinar he delivered in 2012 at his website [peterpappas.com](http://peterpappas.com), there are two key factors driving the increased adoption of the flipped classroom model: poor learning outcomes and prevalence of online video. Based on his report, only 69% of students who start high school finish four years later, and an average of 7,200 students drop out of high school each day, totaling 1.3 million a year. One culprit to this alarming statistics is on the traditional model 'one-size-fits-all' of education teachers have been adopting. This model often results in limited concept engagement and severe consequences. Moreover, the availability of online video and increasing student access to technology has paved the way for flipped classroom models.

As an educator, the researcher never ceases to improve her teaching in order to ensure students' learning by trying out various ways that may seem to work for others and staying updated with current trends in education keeping in mind students' learning styles. It is with this reason that the researcher conceptualized this study.

This study aimed to determine the effects of flipped instruction on the performance and attitude of high school students in Mathematics IV of DMMMSU-MLUC, SY 2014-2015.

Specifically, this study sought answers to the following questions:

1. What is the level of performance of the experimental and control groups in the pretest and posttest in Mathematics IV?
  - 1.1. Is there a significant difference on the level of performance of the two groups of participants in the pretest and posttest in Mathematics IV?
2. What is the level of attitude toward Mathematics IV of the participants in the experimental group before and after the study in terms of the following:
  - a. confidence in Mathematics;
  - b. attitude toward success in Mathematics;
  - c. anxiety toward Mathematics; and
  - d. perception of Mathematics teacher's attitudes?
  - 2.1 Is there a significant difference on the level of attitude toward Mathematics IV of the participants in the experimental group before and after the study in terms of the four attitudinal domains?
3. Is there a significant relationship between the level of Mathematics performance and the level of attitude toward the subject of the experimental group?

## **METHODS**

This study employed the true experimental research design particularly the pretest-posttest control group research design to obtain adequate control of sources of invalidity. Descriptive-correlational research design



**Table 1.** Result of equivalency test

	Mean	Variance	t-Stat
Control Group	87.58	13.17	0.0000
Experimental Group	87.58	13.54	

\* Significant at  $\alpha = 0.05$

was also utilized to determine the level of performance and attitudes of the participants toward mathematics, as well as the extent of relationship between the two variables.

Twenty four (24) fourth year high school students of DMMMSU-MLUC with Mathematics grades ranging from 82-95 were included in the study. There were twelve (12) randomly selected participants for each group. The researcher ensured equivalency of the two groups of participants by randomly selecting students for the control group with almost the same averages as that of their counterparts in the experimental group. To establish equivalency of the experimental and control groups more objectively, t-test was used to check differences on the means of their Mathematics grades. A t statistic equal to 0 compared to a critical t value 2.07 at 0.05 level of significance revealed that there is no significant difference between the two groups of participants (See Table 1). The two groups had almost the same variation in their grades.

Participants in the control group were taught using traditional instruction which made use of the lecture method, boardworks, drills and worksheets singly or in combination. Participants in the experimental group were exposed to flipped instruction with video lectures as homework and drills as classwork. The researcher made every effort to teach the traditional group to the best of her ability so as not to sway the findings of this study.

There were two instruments used in the study: the pretest-posttest on the selected topics in Mathematics IV and the Modified Fennema-Sherman Mathematics Attitude Scale. The pretest-posttest constructed by the researcher was used to gather data in order to determine the performance of the two groups of participants before and after the study. The Modified Fennema-Sherman Mathematics Attitudes Scale was used to gather data pertaining to the attitudinal influence of flipped instruction to the participants in the experimental group. It was a 48- item scale which consisted of four sub-scales, namely: Confidence in Learning Mathematics Subscale, Attitude Toward Success in Mathematics Subscale, Mathematics Anxiety Subscale and Teacher Perceptions Subscale. The Confidence in Learning Mathematics Subscale was intended to measure the confidence in one's ability to learn and to perform well on mathematical tasks. The Mathematics Anxiety Subscale was intended to measure feelings of anxiety, dread, nervousness, and associated bodily symptoms related to doing mathematics. The Attitude Toward Success in Mathematics Subscale aimed to measure students' beliefs about success in learning mathematics. The Teacher Perceptions Subscale was used to assess students' perceptions of how their teachers feel about them as students of mathematics. Each sub-scale consisted of 12 statements related to the learning of mathematics. Six were positively worded and six were negatively worded. Students responded to a statement by indicating the degree to which they agree or disagree with that statement.

The possible responses were "strongly agree", "agree", "undecided", "disagree", and "strongly disagree." The responses were interpreted as follows: SA (Strongly Agree) means the participant was in strong agreement with the attitude item; A (Agree) means the participant was in agreement with the attitude item; U (undecided) means that the participant had no clear-cut decision whether to agree or disagree with the attitude item; D (Disagree) means the participant was in disagreement with the attitude item; SD (Strongly Disagree) means the participant was in strong disagreement with the attitude item. Each response was given a value from 1 to 5, accordingly. Positively-worded statements were scored based on the actual responses of the participants. On the other hand, negatively-worded statements were reversely scored.

The draft of the pretest/ posttest which originally consisted 35 items was reproduced and subjected for pilot testing by the researcher to 30 randomly selected fourth year high school students from Luna National High School, La Union, Philippines.

To establish internal consistency of the 35-item pretest-posttest, the Kuder-Richardson Formula 20 was used. The computed reliability coefficient of 0.82 indicates that the test was reliable. It satisfied the reliability coefficient requirement for a classroom exam which is at least 0.70 (Wells & Wollack 2003). Though the test was highly reliable, two (2) items were discarded due to very low (too easy) and very high (too difficult) difficulty indices. Point biserial values of the items were computed to determine which ones were likely to be unreliable. A recommended point biserial value is at least 0.15 and items with point biserial values lower than 0.15 may need further examination or may be deleted (Varma n.d.). This is the basis on the deletion of eight

(8) more items on the original pretest-posttest. The 35-item pretest-posttest was trimmed down to only 25 items.

The final pretest-posttest was comprised of 25 items. The coefficient of reliability of this test instrument was also computed. The final test was reliable with reliability coefficient of 0.84 which was an improvement from the original test.

To establish content validity of the pretest-posttest, five subject matter experts were asked to evaluate the instrument. The overall median of the valuator's judgments, 4, clearly revealed that the 25-item test was valid.

Data gathered were analyzed statistically by the researcher. Mean was used to determine the level of Mathematics performance of the two groups of participants in the pretest and posttest. The t-test was performed to find out if significant difference existed on the level of performance of the two groups of participants before and after the conduct of the study. Mean gain score and Cohen's d were used to determine the effect size of the use of flipped instruction on Mathematics performance of the participants.

Median was used to compute the level of attitude of the participants in the experimental group in terms of confidence in learning mathematics, attitude toward success in mathematics, mathematics anxiety and perception of teacher's attitudes. Wilcoxon's signed ranks test was used to determine if significant difference existed on the level of attitude of the participants in the experimental group before and after the conduct of the study. Cliff's delta was used to determine the effect size of the use of flipped instruction on participants' attitude toward Mathematics.

Spearman's rank order correlation was used to measure the strength of relationship between the level of performance and the level of attitude of the participants in the experimental group and to determine if significant relationship existed between the two variables.

SPSS and Microsoft Excel were used to facilitate the statistical computation of the data.

## RESULTS

### Level of mathematics performance

Table 2 shows the pretest mean scores of the experimental and control groups, 6.25 and 6.08, respectively. This result indicates that the level of pretest performance of the two groups were both "fair". This is due to the fact that about 91 percent of the participants in each group got scores that are below 10, which means that almost all the participants in each group got unsatisfactory ("poor" and "fair") ratings. This result is expected because the topics included in the test were not yet discussed. The competencies were still about to be learned.

The experimental group had a higher pretest mean score compared to the control group but the performance of the former had much greater variation than that of the latter.

Table 2 further shows that the pretest mean scores of the two groups differ by 0.17 but their level of performance in the pretest did not differ significantly. This was revealed by the computed t value of -0.511 which is higher than the critical value of -2.074. This is attested by the probability value of 0.614 which is higher than the 0.05 margin of error. This means that the experimental group is comparable to the control group in terms of entry characteristics. This implies that the control variable, third quarter Mathematics grade ranging from 82 to 95, was effectively mapped and the random distribution of the participants in the experimental and control groups was of equal chance.

The overall posttest performance of the experimental and control groups were both "very satisfactory" as indicated by their mean scores of 19.33 and 16.75, respectively (See Table 3). The two groups had almost equal variation on their posttest performance. To check whether their posttest mean difference of 2.58 is large enough to support the rejection of the null hypothesis, t-test was performed. It was revealed that their

**Table 2.** Comparative pretest performance of the groups

	Mean	Variance	t-Stat
Control Group	6.08	4.33	
Experimental Group	6.25	7.15	-0.511

\* Significant at  $\alpha = 0.05$

**Table 3.** Comparative posttest performance of the groups

	Mean	Variance	t-Stat
Control Group	16.75	10.39	
Experimental Group	19.33	10.24	-1.97

\* Significant at  $\alpha = 0.05$

posttest performance did not differ significantly as shown by the computed t value of -1.97 which falls on the non-rejection region. This result signifies that there is no significant difference in the posttest performance of the experimental and control groups.

The considerable increase on the marks of the participants in the posttest as compared from that in the pretest can be primarily explained by the fact that the topics were already taught to them. But to have a deeper comparison between the two groups, the point of interest, therefore, is on how much they have improved. The researcher also measured the amount of growth in each group (gain score) and found that from pretest to posttest, the experimental group averaged 9.67% more growth than the traditional group. Table 4 shows that the experimental group had a mean gain score of 13.08 while the control group was 10.67. A t value of -2.12, which is lower than the critical value of -2.074, explains that their gain scores differ significantly. Though the two groups performed basically at the same level in the pretest and posttest, the significant difference on their gain scores suggests that those participants in the experimental group improved better than those in the control group. This implies that the use of flipped instruction had a positive effect on the mathematics performance of the participants in the experimental group. But as to what extent is the effect of flipped instruction on the mathematics performance can be explained by the effect size. The effect size based on the gain scores computed using Cohen's d was 0.9. This result can be interpreted as "large effect" based on Cohen's standard (Becker 2000). Thus, it can be said that flipped instruction had a large effect on the improvement of mathematics performance of the participants. This is because within the flipped model students were better able to prepare for the class sessions and had more opportunities to interact with the instructor and peers than during traditional lectures.

This finding is parallel with other researches conducted, which found similar results in other subject areas, including calculus, chemistry, physics, and engineering (Sahin et.al 2014, ALRowais 2014, Bell 2015, Chester et. al. 2011). Further, with regards to the effect of flipped instruction on students' performance, some studies showed that improvement on student learning and total comprehension took place in the flipped classroom. Ruddick (2012) reported that there were significant improvements on students' scores in the flipped classroom compared to student scores in the traditional classroom. Further, in a study at Virginia State University found that students in a flipped classroom environment scored 8.6% better in the class on average over the traditionally taught course (Talley & Scherer 2013). These results clearly show that flipped instruction has a positive effect on students' performance.

### Attitude toward mathematics

Before the study, the experimental group had its highest median rating in terms of perceptions of teacher's attitudes whereas its lowest mean rating was in terms of mathematics anxiety (See Table 5). This result shows that the students' anxiety towards Mathematics does not necessarily caused by teacher's disposition. It may be attributed by other factors such as unpleasant experiences related to the study of Mathematics. The overall attitude toward mathematics of the participants in the experimental group before they were exposed to flipped instruction was "highly favorable" as indicated by the median rating of 4. It seems that the attitude of the participants toward Mathematics did not change after the study as shown by the overall median rating on the four attitudinal domains which was still 4. A number of participants exhibited the same responses for particular items before and after the study. This result may be explained, in part, by the time frame of the study. One cannot expect a sudden favorable change in attitude in a short period of time. However, it is

**Table 4.** Comparison on the gain scores of the two groups

	Mean	Variance	t-Stat	d
Control Group	10.67	7.51	-2.12*	0.9
Experimental Group	13.08	8.08		

\* Significant at  $\alpha = 0.05$

**Table 5.** Attitude test result of the experimental group

	Median		W	d
	Before	After		
Confidence in Mathematics	3.50	3.75	6	0.33
Attitude toward success in Mathematics	3.50	4.00	16	0.06
Anxiety toward Mathematics	3.00	3.00	2	0.00
Perception of Mathematics teacher's attitudes	4.00	4.00	15	0.02
Overall Attitude	4.00	4.00	10	0.00

\* Significant at  $\alpha = 0.05$

interesting to note that students had somehow gained more confidence in learning Mathematics and had better attitude toward success in Mathematics after the study as indicated by the increase in their median ratings of these two domains after the study. This means that the participants in the experimental group benefited from the flipped instruction when it comes to boosting their confidence and developing more positive attitude toward success in Mathematics. Students in the flipped class were more confident after the study because they did not feel anxious of missing or not understanding the material (Ruddick 2012) because they could re-watch the videos over and over again the videos when they miss something (Brunsell & Horejsi 2013) and could ask questions during class sessions with their instructor or peers. Students' responses showed that flipped instruction prepared them better and enabled them to feel more confident in learning mathematics. Again, this finding can be seen to stem from the fact that students in the flipped classroom model have more freedom and flexibility to choose their preparation methods for the class (Fulton 2012). In fact, flipping the class even helps in sparking and retaining student interest in mathematics as reported by the study of Love et al. (2014) on flipping the linear algebra classroom. Their study found that flipped instruction students in the flipped classroom enjoyed the classes more.

Wilcoxon's signed ranks test revealed that there is no significant difference on the attitude of the experimental group toward Mathematics before and after the study on the four attitudinal domains. Moreover, the effect size of the use flipped instruction on the attitude of the participants is almost negligible. This result suggests that flipped instruction had no significant effect on the overall attitude of students.

However, some of the findings from researches conducted thus far would indicate that flipped instruction has a positive effect on students' attitude. In a survey of more than 500 teachers, 80% of them reported that flipping the classroom improved students' attitude (Brunsell & Horejsi 2013). The study of Moore and Chung (2015) among twenty-five high school students revealed that the perceptions and attitudes of the participants were generally positive in the flipped classroom environment and that the students were motivated to use the web-based instructional videos to prepare for their expected learning outcomes. Their study lasted for four months and employed varied data gathering procedures such as survey, interview and observation. Moreover, the study of ALRowais (2014) showed that there was a positive effect of flipped model of instruction on both the students' achievement and their attitudes towards studying higher education courses. Additionally, Chester et al. (2011) found that a flipped classroom improves student behavior. The present study would have had similar results probably if the experimentation lasted longer and the data were analyzed using both quantitative and qualitative methods.

### Mathematics performance versus attitude toward mathematics

Table 6 shows the result of the correlation test between the level of Mathematics performance and attitude of the experimental group toward Mathematics. Using the rule of thumb, the coefficient of correlation of 0.028 (lower than the critical value 0.648 at  $\alpha = 0.05$ ) indicates that there is very small association between the level of Mathematics performance and attitude of the experimental group toward Mathematics and that the relationship is not significant at 0.05 margin of error. This means that there is no significant relationship between the level of performance and attitude towards mathematics of the participants in the experimental group. Having favorable attitude appears to have no significant effect on getting good marks.

On the other hand, several research findings show that relationship exists between math achievement and attitudes towards mathematics and even posit that good achievers develop more positive attitudes than lower achievers (Mata et.al 2012, Lipnevich et.al. 2011, Sanchez et. al. 2004, Singh et.al. 2010). Additionally, DePaolo and McLaren (2006) found out that attitude has an impact on performance. Their study found that relationship between negative attitudes and poor exam performance appears to be particularly strong. Further, a study (Schenkel 2009) found that positive attitude about mathematics does have a positive impact on a student's classroom performance.

**Table 6.** Result of correlation test

	Average	r
Performance	19.33	
Attitude	4	0.028

\* Significant at  $\alpha = 0.05$

## REFERENCES

- ALRowais, A., 2014. The impact of flipped learning on achievement and attitudes in higher education, *International Journal for Cross-Disciplinary Subjects in Education (IJCDSE)*, 4(1). Retrieved from <http://www.infonomics-society.org/IJCDSE/TheImpactofFlippedLearningonAchievementandAttitudesIn20HigherEducation.pdf>.
- Becker, L. A., 2000. *Effect size*. Retrieved from <http://www.bwgriffin.com/gsu/courses/edur9131/content/EffectSizeBecker.pdf>.
- Bell, M. R., 2015. An investigation of the impact of a flipped classroom instructional approach on high school students' content knowledge and attitudes toward the learning environment. (*Graduate Thesis*, Brigham Young University). Retrieved from <http://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=5443&context=etd>.
- Brunsell, E. and Horejsi, M., 2013. Flipping your classroom in one "take". *The Science Teacher*. Retrieved from <https://www.questia.com/library/journal/1G1-323260080/flipping-your-classroom-in-one-take>.
- Chester, A., Buntine, A., Hammond, K. and Atkinson, L., 2011. Podcasting in education: student attitudes, behaviour and self efficacy. *Educational Technology & Society*, 14(2), pp.236-247. Retrieved from [http://www.ifets.info/journals/14\\_2/20.pdf](http://www.ifets.info/journals/14_2/20.pdf).
- Deci, E. L. and Ryan, R. M., 2000. Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology*, 25(1), pp.54-67.
- DePaolo, C. and McLaren, C. H., 2006. The relationship between attitudes and performance in business calculus, *INFORMS Transactions on Education*, 6(2). Retrieved from <http://ite.pubs.informs.org/Vol6No2/DepaoloMclaren/>.
- DeVaney, T. A., 2012. Anxiety and attitude of graduate students in on-campus vs. online statistics courses. *Journal of Statistics Education*, 18(1). Retrieved from <http://www.amstat.org/publications/jse/v18n1/devaney.pdf>.
- Finney, S. J. and Schraw, G., 2003. Self-efficacy beliefs in college statistics courses (Abstract). *Contemporary Educational Psychology*, 28(2), pp.161-186. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0361476X02000152>.
- Fulton, K., 2012. Upside down and inside out: flip your classroom to improve student learning. *Learning & Leading with Technology*, 39(8), pp.12-17. Retrieved from <http://files.eric.ed.gov/fulltext/EJ982840.pdf>.
- Gaughan, J. E., 2014. The flipped classroom in world history. *The History Teacher*, 47(2), pp.221-244. Retrieved from [http://www.societyforhistoryeducation.org/pdfs/F14\\_Gaughan.pdf](http://www.societyforhistoryeducation.org/pdfs/F14_Gaughan.pdf).
- Kim, K. J. and Bonk, C. J., 2006. The future of online teaching and learning in higher education: The survey says... *EDUCAUSE Quarterly*, 29(4), pp.22-30. Retrieved from <http://er.educause.edu/~media/files/article-downloads/eqm0644.pdf>
- Lipnevich, A. A., MacCann, C., Krumm, S., Burrus, J. and Roberts, R. D., 2011. Mathematics attitudes and mathematics outcomes of US and Belarusian middle school students (Abstract). *Journal of Educational Psychology*, 103(1), pp.105-118. Retrieved from <http://eric.ed.gov/?id=EJ933605>.
- Love, B., Hodge, A., Grandgenett, N. and Swift, A. W., 2014. Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology*, 45(3), pp.317-324. Retrieved from <http://www.tandfonline.com/doi/full/10.1080/0020739X.2013.822582>.
- Margulieux, L. E., Bujak, K. R., McCracken, W. M. and Majerich, D. M., 2014. Hybrid, blended, flipped, and inverted: defining terms in a two dimensional taxonomy. *HICE Conference Proceedings*. Retrieved from [http://c21u.gatech.edu/sites/default/files/HICEConferenceProceedings\\_1556\\_with\\_citation\\_\[4\].pdf](http://c21u.gatech.edu/sites/default/files/HICEConferenceProceedings_1556_with_citation_[4].pdf).
- Mata, M. D., Monteiro, V. and Peixoto, F., 2012. Attitudes towards mathematics: effects of individual, motivational, and social support factors. *Child Development Research*. Retrieved from <http://www.hindawi.com/journals/cdr/2012/876028/>.
- McLeod, S. A., 2010. *Simply Psychology; Zone of Proximal Development*. Retrieved from <http://www.simplypsychology.org/Zone-of-Proximal-Development.html>.
- Moore, C. and Chung, C., 2015. Students' attitudes, perceptions, and engagement within a flipped classroom model as related to learning mathematics. *Journal of Studies in Education*, 5(3). Retrieved from <http://www.macrothink.org/journal/index.php/jse/article/viewFile/8131/6686>.
- Ruddick, K. W., 2012. Improving chemical education from high school to college using a more hands-on approach. (*Doctoral Dissertation*, University of Memphis). Retrieved from <http://gradworks.umi.com/35/29/3529991.html>.
- Sahin, A., Cavlazoglu, B. and Zeytuncu, Y. E., 2015. Flipping a college Calculus course: a case study. *Educational Technology & Society*, 18(3), pp.142-152. Retrieved from [http://www.ifets.info/journals/18\\_3/11.pdf](http://www.ifets.info/journals/18_3/11.pdf).
- Sanchez, K., Zimmerman, L. and Ye, R., 2004. Secondary students' attitudes toward mathematics. *Academic Exchange Quarterly*. Retrieved from <https://www.questia.com/library/journal/1G1-121714089/secondary-students-attitudes-toward-mathematics>.
- Schenkel, B., 2009. The impact of an attitude toward Mathematics on Mathematics. (*Graduate Thesis*, Marietta College). Retrieved from [https://etd.ohiolink.edu/rws\\_etd/document/get/marietta1241710279/inline](https://etd.ohiolink.edu/rws_etd/document/get/marietta1241710279/inline).
- Singh, K., Granville, M., and Dika, S., 2010. Mathematics and science achievement: effects of motivation, interest, and academic engagement. *Journal of Educational Research*. Retrieved from <http://www.tandfonline.com/doi/abs/10.1080/00220670209596607>.

- Talbert, R., 2012. Inverted classroom. *Colleagues*, 9(1), Retrieved from <http://scholarworks.gvsu.edu/colleagues/vol9/iss1/7>.
- Talley, C. P. and Scherer, S., 2013. The enhanced flipped classroom: increasing academic performance with student-recorded lectures and practice testing in a “flipped” STEM course. *Journal of Negro Education*, 82(3), pp.339-347.
- Varma, S., 2006. Preliminary item statistics using point-biserial correlation and p-values. *Educational Data Systems Publications*, Retrieved from: [http://www.eddata.com/resources/publications/EDS\\_Point\\_Biserial.pdf](http://www.eddata.com/resources/publications/EDS_Point_Biserial.pdf).
- Wells, C. S. and Wollack, J. A., 2003. *An Instructor's Guide to Understanding Test Reliability*, Retrieved from: <http://testing.wisc.edu/Reliability.pdf>.

# Learning the language of earth science: Middle school students' explorations of rocks and minerals

Angelia Reid-Griffin<sup>1\*</sup>

<sup>1</sup>University of North Carolina Wilmington, USA

## ABSTRACT

The approaches and interpretations of a class of 6th graders and a class of 8th graders in a U.S. middle school asked to engage in tasks that involved using observations to describe and classify samples is the subject of this paper. Overall 8th graders were better able to perform the tasks, suggesting a developmental advantage aspect. However, the descriptions of the rock and mineral samples recorded by students can be considered salient for identification purposes. However, the descriptions were not recognized as salient features by most of the grade 6th and 8th U.S. students.

## Keywords

geology,  
earth science,  
perception,  
middle school,  
structure

Received: 29 Jan 2016

Revised: 12 Feb 2016

Accepted: 5 Mar 2016

DOI: 10.20897/lectito.201621

## INTRODUCTION

The National Science Education Standards outlined a developmentally sound scheme for introducing the appropriate earth science topics at the elementary, middle, and high school years (National Research Council 1996). For students in United States middle schools, grades 5-8, the focus of the content standard includes: the earth's structure, history and position in the solar system. Although teaching students about abstract concepts such as the formation and structure of the earth and solar system may be challenging it is important to instruct them at this level so that when they graduate from high school they have a deep understanding of earth science concepts. This also includes having knowledge of natural processes and cycles, a sense of time scales, which is a concept that is difficult for some adults, and the continuous evolving of subsystems (Mayer & Armstrong 1990; Kortz & Murray 2009).

One fundamental aspect of learning about the structure of the earth for students in the middle grades is based on their knowledge of the earth structure, abilities to conduct experimental observations and describe geological conceptions of rock formations and property identifications. In order for students to develop an understanding of the geological aspects of the earth they must possess the skills to make good observations and clearly explain the relevance of the properties they discover. According to the National Science Education Standards (National Research Council 1996) students at the middle and high school level have the ability to record observations and distinguish characteristic properties. Having good observation techniques allow students to better understand the geochemical and geophysical processes involved in learning about the structure and history of the earth. In conducting activities such as describing and classifying rock types, middle school students have some level of experience and expertise as they are able to make observations based on their knowledge of history and rock formations (Ault 1998; Ford 2005). Rock identification tasks at

\*Correspondence to: griffina@uncw.edu

the middle school level can help students further develop their skills of observation and enhance use of scientific inquiry as they employ knowledge, observations, ideas, and questions (National Research Council 1996, p. 143). This paper explores how middle school students use observation skills to make distinctions among samples and describe the geological relevance of the properties of the samples identified. Often time presented during the elementary geology curricula, rocks and minerals tasks taught at the middle school provides learner the ability to make connections between rock and mineral properties to rock formations. As noted by Ford (2005) students will have difficulty understanding the task if they are not able understand how the properties they observe link to the geological processes involved in the earth's formations.

A critical element for understanding geological processes for middle school students and even older students can be identified by their cognitive understanding of rock formations and structure and the ability to explain and describe the relevance of properties explored in rock or mineral samples. According to research studies (Blake 1999; Ford 2005; Happs 1982, 1985; Lillo 1994; Oversby 1996; Marques & Thompson 1997; Russell Bell Longden & McGuigan 1993; Sharp Mackintosh & Seedhouse 1995) conducted in the United States and Europe, children are able to develop conceptual understandings of the geosphere and its physical properties such as rocks and minerals and structural makeup. However, students' explanations and descriptions of geological aspects are limited as compared to geologists that have complex understandings of the theoretical constructs specific to earth science. Efforts have been made to transform the science curriculum to meet the needs of the learners by offering hands-on, inquiry-based earth science activities for learning these concepts (American Geological Institute 2006; Ault 1982; Blake 2004; Johnson 2004; Smith 1988). Even with these changes in the curriculum, some middle grades students continue to have difficulty grasping an understanding of many of geological processes, therefore failing to comprehend the properties and structure of the geosphere. In some adults it has been noted that they also have difficulty connecting the theoretical constructs of the earth system (Hawley 2002). Finding an earth science curriculum that will result in students understanding the key properties as they relate to rock formations and the earth structure is important for science educators. We have to make sure all students have a good understanding of earth science concepts before graduating K-12 schools. Therefore, our exploration of middle schools' students' understanding of earth science concepts is guided by the task of describing and classifying rocks and these questions: 1) How do 6<sup>th</sup> and 8<sup>th</sup> graders approach the task of identification? And 2) How do middle school students describe rocks?

The use of models in teaching students about geological concepts has found to be common in many studies. Addressing the aspects of learning is important as we attempt to understand students' content knowledge, process and inquiry skills and epistemic understanding of the geological concepts. Blake's review of literature on children's understanding in earth science (2004) indicated that instruction that promotes cognitive change and values the use of analogies serves as the focus of research models in teaching novices about geological concepts. Although many studies have shown providing relevant analogies to children can help scaffold their knowledge of concepts these children oftentimes revert to "non-scientific" explanations of concepts outside of classroom settings (Blake 2004; Happs 1984). In this study we implemented instruction to examine middle school students' transition from "non-scientific" to "pro-scientific" explanation of how rocks and minerals are described and classified. "Pro-scientific" is similar to Blake's (2004) concept "proto-scientific" in which learner utilizes both prior knowledge and experiences, unscientific in nature, along with acquired scientific conceptions to explain a phenomena or concept.

Research studies also indicate that tasks presented at a superficial level can limit students' understanding of the earth (Happs 1982; Blake 2004; Ford 2005; Dal 2006). Hawley (2002) reported that children don't have a good understanding of rocks and neither do adults. He pointed out how characteristics that were salient to some of the students were not those characteristics that scientists use to identify rocks. Ford (2005) observed two classes of third graders who wrote descriptions of rocks and minerals as part of an activity in an earth materials unit. Ford reported that the descriptions that students wrote were not always the ones important for the identification of rocks and minerals. For example, some of the observations focused on characteristics of rock that had nothing to do with their origin but more with the characteristics of wear and tear, for example chipping. Ford (2005) concluded that students may not recognize those characteristics that are defining ones for a particular rock but may focus on those characteristics that are more obvious. Colors were most often used to identify minerals and texture was used most frequently for rocks. However, texture was not linked to grain size but to the feel of the rock. Oversby (1996) examined the topic of rock identification with middle and high school students and college students who were post graduate science teachers and post graduates not in a science field and found that the topic was difficult for all participants. He proposed that part of the



issue with understanding rocks is the use of common terms that do not align with the definition of a rock. For example, one student defined a stone as a “loose rock”. He felt lack of understanding of what defined a rock was a barrier to any further understanding. In an examination of eighth graders’ discussions of the rock cycle Rosenberg, et al. (2006) noted that students try to use vocabulary that is in the unit whether or not they know what the word means.

## METHODS

### Setting and participants

The study focuses on middle school students enrolled in an optional course offered at the local middle school for 6<sup>th</sup> and 8<sup>th</sup> grade students. As a naturalist study, the site of the research and subjects were chosen to provide us with rich information to best answer our exploratory questions. We employed this qualitative approach to identify the conceptions of students as they approached the task of describing and classifying rock types. The research study took place at a rural middle school located in southeastern United States. The student population consisted of students from varied socioeconomic status and ethnicities. Self-selected small groups consisting of three students worked through the small group activities throughout the term of the project. During the 6 week period of the course, several earth science topics were selected for study including maps and mapping, rocks, stratigraphy, and volcanoes. Middle grade students respond best to actively constructing understanding so instructional activities were chosen with this characteristic in mind. Topics were selected for their alignment with the state’s Standard Course of study and for their spatial components since spatial cognition was the overarching focus of the large scale study.

The study examines the tasks assigned to 6<sup>th</sup> grade and 8<sup>th</sup> grade students enrolled in the six week elective science course focused on earth science topics. The classes consisted of 17 and 18 students respectively. These students were selected by the principal; the criteria for selection were to have a classroom with student demographics that matched that of the school, and to have students who had a scholastic grade average for their class of 85 percent or better. These criteria were used to promote the exploratory study and to ensure enrolled students were motivated to complete the tasks and also increase the chance that students would be willing and able to communicate their ideas to the researchers as well as their peers. The teachers of the course were university science education faculty members who designed the instructional content of the course. The teachers were knowledgeable of the earth science curriculum and were capable of employing a constructivist model of teaching and learning (Dal 2007) (See Table 1).

**Table 1.** Breakdown of sixth and grade students by ethnicity and gender

	6 <sup>th</sup>	8 <sup>th</sup>	Total
Ethnicity			
African American	6	6	12
Caucasian	11	10	21
Hispanic	0	2	2
Total	17	18	35
Gender			
Males	9	9	18
Females	8	9	17

### 3D GeoMapping

The exploratory course was called, “3D GeoMapping” and included three modules dealing with 2D and 3D spatial objects such as flat maps, contour maps and sub-surface mapping. There was no textbook used for this course. Most of the activities were carried out in small groups of 3-4 members (six groups per class) with whole group discussions following to assist students with making connections between activities and related concepts. Student groups were self selected and instructed to work as equally contributing members and to come to a consensus before recording answers.

### Data collection and analysis

For this study, researchers observed and collected notes on students’ approaches throughout the six week course. The primary data sources included transcripts of students’ verbal interactions and videotapes during small group work. We specifically relied on students’ work and transcribed observations as they identified the rocks samples. Analyses of the subset of activities were initially coded for underlying themes using constant

comparative analysis (Glaser & Strauss 1967; Lincoln & Guba 1985). Final coding emerges the themes from the data, which is a reflection of the students' answers as they completed the rock description and classification tasks.

### Description of activities

*Rock identification.* This activity began with students examining examples of seven numbered sedimentary rocks and recording observable characteristics of each rock. Some characteristics that students were to record were identified for them (color, grain size, hardness, presence of fossils); they could choose to record any other observable qualities they thought were important. Then they were given a chart with the names of the seven sedimentary rocks followed by a picture, a list of observable qualities and the depositional environment. They were to identify the seven types of sedimentary rocks they had been given by comparing their observations with the descriptions on the key. They then answered a sheet that asks them to compare the origins of the different types of rocks, and the environmental conditions under which they were formed. The approach of the small groups in grades 6 and 8 to describe and classify the rocks was analyzed and is reported in the results section (See Table 2).

**Table 2.** Handout students used to complete task. modified worksheet from Ward (1999) Natural Science Establishment

Sample Number	Observable Characteristics	Rock Name	Depositional Environment (Probable)
1.	This rock is very smooth and thin. It is very light-weight. It has a fossil of a leaf inside. They have small grains.	Carbonaceous shale	Swamp, lowlands
2.	It has a grayish color. Its' smooth. It's not too heavy. They have small grains. It has white-chalky stuff on it	Argillaceous shale	River, delta, muddy sea
3.	It is clear. It is smooth. It is moist, oily, and slick. It has a big grain size. It is not too heavy. It looks like an ice cube Smells like vanilla & cinnamon	Halite (rock salt)	Salt Lake
4.	It is hard and rough. It reminds me of brick. The grain size is rather small. It is light. It is not real big. Smells like dirt	Sandstone	Beach, river or delta
5.	It is rough. There are lots of different colors of rocks. It is also made of dirt. It looks like a cookie. Is rounded. It is a chunk of mud Smells like burnt rubber	Conglomerate	Beach, river
6.	This rock is black. It is light. It is very shiny. It is smooth on the sides and rough on the top. The grain are bigger	Coal	Swamp
7.	This rock is gray and white. It is heavy and rough. It has fossils of seashells inside. The grains are rather larger	Fossiliferous limestone	Clear shallow marine sea

## RESULTS

### Strategies used by 6<sup>th</sup> graders

Five of the six groups of 6<sup>th</sup> graders used very similar strategies in identifying the rocks. Four of the six groups immediately identified halite because it was so clearly distinguishable when compared to the other samples. There were a number of strategies, which emerged to identify the other rocks but most noticeable as a poor strategy was the students' attempts to match the pictures on the chart (key) with the rocks and minerals. The pictures on the chart were small and in black and white so characteristics of individual rocks were difficult to distinguish. Nevertheless, students would put the sample next to each picture, occasionally making a correct identification from the picture. In five of the six groups, this strategy was used by a least one member of the groups. Another favorite strategy of sixth graders was to immediately default to color. Sometimes a member of the group would recognize that more than one rock had the same color. In other cases, the first rock or mineral that was listed on the sheet that matched the sample's color was chosen. Prior knowledge occasionally played a role. For example, one group member had experiences with coal and was

able to immediately identify it. In two groups the presence of fossils was used as a determining factor. In one group the members did not understand there was a one-to-one correspondence between the samples and the rocks and minerals listed on the key. So the members depended, rather unsuccessfully, to identify samples based on prior knowledge. Students held on to alternative conceptions for identifying rocks and minerals such as use of smell and color rather than using key and pointing out salient features of the samples (See Figure 1).

### Strategies used by 8<sup>th</sup> graders to identify rocks

As with the sixth graders, halite was readily identified by the groups. For all six groups of eighth graders color was the usually the first characteristic they tried to match. However, when group members would notice that color did not narrow down the choice to one sample they looked for other characteristics they had observed. Although some group members looked at pictures that was not a primary strategy and confirming

Based on these descriptions and your knowledge of sedimentary rock types, identify the rocks using the following names:

Argillaceous Shale	Red Sandstone	
Coal	Carbonaceous Shale	
White Sandstone	Fossiliferous Limestone	
Rock Type 1	<u>Red Sandstone</u>	Color for Model Red
Rock Type 2	<u>Carbonaceous shale</u>	Green
Rock Type 3	<u>Coal</u>	Black
Rock Type 4	<u>White Sandstone</u>	White
Rock Type 5	<u>Fossiliferous Limestone</u>	Blue
Rock Type 6	<u>Argillaceous Shale</u>	Brown

Based on these descriptions and your knowledge of sedimentary rock types, identify the rocks using the following names:

Argillaceous Shale	Red Sandstone	
Coal	Carbonaceous Shale	
White Sandstone	Fossiliferous Limestone	
Rock Type 1	<u>Red Sandstone</u>	Color for Model Red
Rock Type 2	<u>Carbonaceous shale</u>	Green
Rock Type 3	<u>Coal</u>	Black
Rock Type 4	<u>White Sandstone</u>	White
Rock Type 5	<u>Fossiliferous Limestone</u>	Blue
Rock Type 6	<u>Argillaceous shale</u>	Brown

Based on these descriptions and your knowledge of sedimentary rock types, identify the rocks using the following names:

Argillaceous Shale	Red Sandstone	
Coal	Carbonaceous Shale	
White Sandstone	Fossiliferous Limestone	
Rock Type 1	<u>Red sandstone</u>	Color for Model Red
Rock Type 2	<u>Carbonaceous shale</u>	Green
Rock Type 3	<u>coal</u>	Black
Rock Type 4	<u>white sandstone</u>	White
Rock Type 5	<u>Fossiliferous limestone</u>	Blue
Rock Type 6	<u>Argillaceous shale</u>	Brown

**Figure 1.** Student sample responses

characteristics were always sought. Although eighth graders were slightly more successful in identifying the rocks and minerals, errors were made when students did not recognize the importance of a particular characteristic such as presence of a type of fossil (See Table 3).

## DISCUSSION

Saliency and scale both played a key role in the completion and interpretation of the students' tasks. Characteristics most likely to appear salient have been used during prior experiences as defining properties and retrieved from long-term memory for use in working memory. To experts, (such as science teachers), salient characteristics are obvious but not to novices. For example, without an understanding of the origin of certain rock, characteristics such as grain size, texture, or cleavage may not be salient while more common characteristics such as color, shape, or cracks may be. Therefore, students focus on, what to them, are the features that will be helpful in identification of the rocks. Color is one of the earliest characteristics used for identification (typically before preschool age). Without experiences in using salient features for rock identification then characteristics used for prior identification tasks will not be accessed.

In many cases, color is the obvious default. Therefore students must have the experience of using and understanding how other characteristics are the salient ones for rock identification tasks. Then when faced with rock identification tasks at a later time, prior experiences will assist students with bringing to working memory the salient features appropriate for the task.

In comparison to Hawley (2002 p. 370) approach to teaching students about rocks our pedagogical approach of scaffolding and using relevant analogies allowed the students to “determine, recognize and explain fundamental textural differences in a range of rocks and relate them to specific rock properties.” By focusing on the grain relationships of rocks and using an inquiry approach during course instruction, students were able to acquire knowledge to think scientifically about rocks and earth science concepts. Although the terminology used by the students in our population as they described the rocks showed some consistency, they may not be fully representative of all students in this middle school population. Additional research is needed to determine if all middle school students hold on to similar conceptions of knowledge when describing and classifying these geological structures.

## IMPLICATIONS

So clearly a teacher must consciously make salient key characteristics. Students at this age, 11-14, may have little experience with constructing knowledge for themselves or lack sufficient prior knowledge to pick out salient features. One suggestion might be to limit students' descriptions of rock characteristics to those most important to identification. This might encourage the development of rock type identification schema that includes salient features. Some researchers propose that students must have a grasp on geological time to understand geology and as a first step must be able to engage in diachronic thinking. Diachronic thinking as described by Montangero (1996) occurs when an individual must mentally construct change as it has happened over time. He reported that children as young as 10-11 could engage in diachronic thinking but only if they had knowledge of the particular targeted concept. In other words, students may be able to think about and follow the changes over time as it relates to aging of a pet or passing of the seasons. But without the necessary geological information, understanding a concept such as deposition may not be possible even if diachronic thinking is possible.

Therefore earth science instruction should provide scaffolding and the use of relevant analogies to enable students' transition from “non-scientific” explanation of geologic concepts to “pro-scientific” and eventually scientific explanations of how rocks and minerals are described and classified.

## REFERENCES

- American Geological Institute, 2006. *Curriculum materials for teachers*.  
[Http://www.agiweb.org/education/teachers/curriculum\\_materials.html](http://www.agiweb.org/education/teachers/curriculum_materials.html) (Accessed 28 June 2010.)
- Ault, C. R., 1982. Time in geological explanation as perceived by elementary-school students. *Journal of Geological Education*, 30, pp.304-309.
- Ault, C. R., 1998. Criteria of excellence for geological inquiry: The necessity of ambiguity. *Journal of Research in Science Teaching*, 35(2), pp.189-212.
- Blake, A., 1999. *Children's understanding of aspects of earth science at key stage 2: Conceptions and conceptual change*. (PhD thesis, University of Newcastle).

- Blake, A., 2004. Helping young children see what is relevant and why: Supporting cognitive change in earth science using analogy. *International Journal of Science Education*, 26, pp.1855-1873.
- Blake, A., 2005. Do young children's ideas about the Earth's structure and processes reveal underlying patterns of descriptive and causal understanding in earth science. *Research in Science and Technological Education*, 23, pp.59-74.
- Dal, B., 2006. The origin and extent of student's understandings: The effect of various kinds of factors in conceptual understanding in volcanism. *Electronic Journal of Science Education*, 11, pp.38-59, viewed 2 August 2010 <http://ejse.southwestern.edu>
- Dal, B., 2007. How do we help students build beliefs that allow them to avoid critical learning barriers and develop a deep understanding of geology?. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(4), pp.251-269.
- Ford, D. J., 2005. The challenges of observing geologically: Third graders' descriptions of rock and mineral properties. *Science Education*, 89, pp.276-295.
- Hawley, D., 2002. Building conceptual understanding in young scientists. *Journal of Geoscience Education*, 50, pp.363-371.
- Happs, J. C., 1982. *Some aspects of student understanding of rocks and minerals*. University of Waikato: Science Education Research Unit Working Paper.
- Happs, J. C., 1984. *The utility of alternative knowledge frameworks in effecting conceptual change: Some examples from the earth sciences*. (PhD thesis, University of Waikato, New Zealand.
- Happs, J. C., 1985. Regression in learning outcomes: Some examples from earth sciences. *European Journal of Science Education*, 7, pp.431-433.
- Johnson, C. J., 2004. NANA "Rocks" problem-based learning. *Science Scope*, 28, pp.48-49.
- Kortz, K. and Murray, D., 2009. Barriers to college students learning how rocks form. *Journal of Geoscience Education*, 57(4), pp.300-315.
- Lillo, J., 1994. An analysis of the annotated drawings of the internal structure of the Earth made by students aged 10-15 from primary and secondary schools in Spain. *Teaching Earth Sciences*, 19(3), pp.83-87.
- Lincoln, Y. and Guba, E., 1985. *Naturalist inquiry*. Newbury Park CA: Sage.
- Marques, L. and Thompson, D., 1997. Portuguese students' understanding at ages 10-11 and 14-15 on the origin and nature of the earth and the development of life. *Research in Science and Technological Education*, 15, pp.29-51.
- Mayer, V. J. and Armstrong, R. E., 1990. What every 17-year old should know about planet earth: The report of a conference of educators and geoscientists. *Science Education*, 74, pp.155-165.
- Montangero, J., 1996. *Understanding changes in Time: The development of diachronic thinking in 7- to 12-year old children*. Bristol, PA: Taylor & Francis.
- National Research Council, 1996. *National science education standards*. Washington, DC: National Academy Press.
- Oversby, J., 1996. Knowledge of earth science and the potential for its Development. *School Science Review*, 78, pp.91-97.
- Rosenberg, S., Hammer, D. and Phelan, J., 2006. Multiple epistemological coherences in an eighth grade discussion of the rock cycle. *The Journal of Learning Sciences*, 15, pp.261-292.
- Russell, T., Bell, D., Longden, K., and McGuigan, L., 1993. *Primary SPACE research report: Rocks, soil and weather* Liverpool: Liverpool University Press.
- Sharp, J. G., Mackintosh, M. A. P. and Seedhouse, P., 1995. Some comments on children's ideas about Earth structure, volcanoes, earthquakes and plates. *Teaching Earth Sciences*, 20(1), pp.28-30.
- Smith, G. S., 1988. Gaps in the rock and fossil records and implications for the rate and mode of evolution. *Journal of Geological Education*, 36, pp.143-146.



<http://www.lectitopublishing.nl>



<https://www.facebook.com/LectitoJournals/>



<https://twitter.com/lectito1>



<https://www.linkedin.com/in/lectito-journals-9a675010b/>

*This page intentionally left blank.*

<https://www.lectitopublishing.nl>