Investigating the Impact of Computational Modeling on Students' Conceptual Understanding of Force and Motion

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Introduction

Problem

- The Next Generation Science Standards (NGSS) identified modeling and computational thinking as part of the eight science and engineering practices (Lead States, 2013).
- Advances in computing and information technologies have further emphasized the centrality of modeling in science by making model building more accessible to scientists today (Schwarz & White, 2015).
- Previous research shows that most students do not engage in model building activities in K-12 formal classroom settings (Schwarz & Gwekwerere, 2007).

Research Questions

1. How does building simulation-based computer models of physical phenomena through a visual programming environment in a week-long classroom intervention influence middle school students' conceptual understanding of force and motion concepts?
2. Is there a differential impact of the classroom intervention on students' conceptual understanding of force and motion concepts according to students' gender?

Method

Theoretical Framework

- The Representational Construction Affordances (RCA) framework (Prain & Tytler, 2012) explains how and why students learn through generative activity of constructing their own representations.

Participants

- This study took place in a public middle school. The sample consisted of seventh-grade students (*N* = 82).
- 54% of the students were male.
- The age of the students varied from 12 to 14 years with an average of 12.69 (*SD* = .52).

Data Sources and Analysis

- Data sources included a pre- and post-test of a 16-item Force and Motion multiple choice assessment, and structured interviews with a subset of the participating students (*n* = 12).
- A paired samples t-test was conducted to determine if there were any statistically significant differences between students' pre- and post-test scores. Audio recordings of students' interview responses were transcribed verbatim and qualitatively analyzed by two researchers using open coding approach to identify the emergent themes (Creswell, 2015).

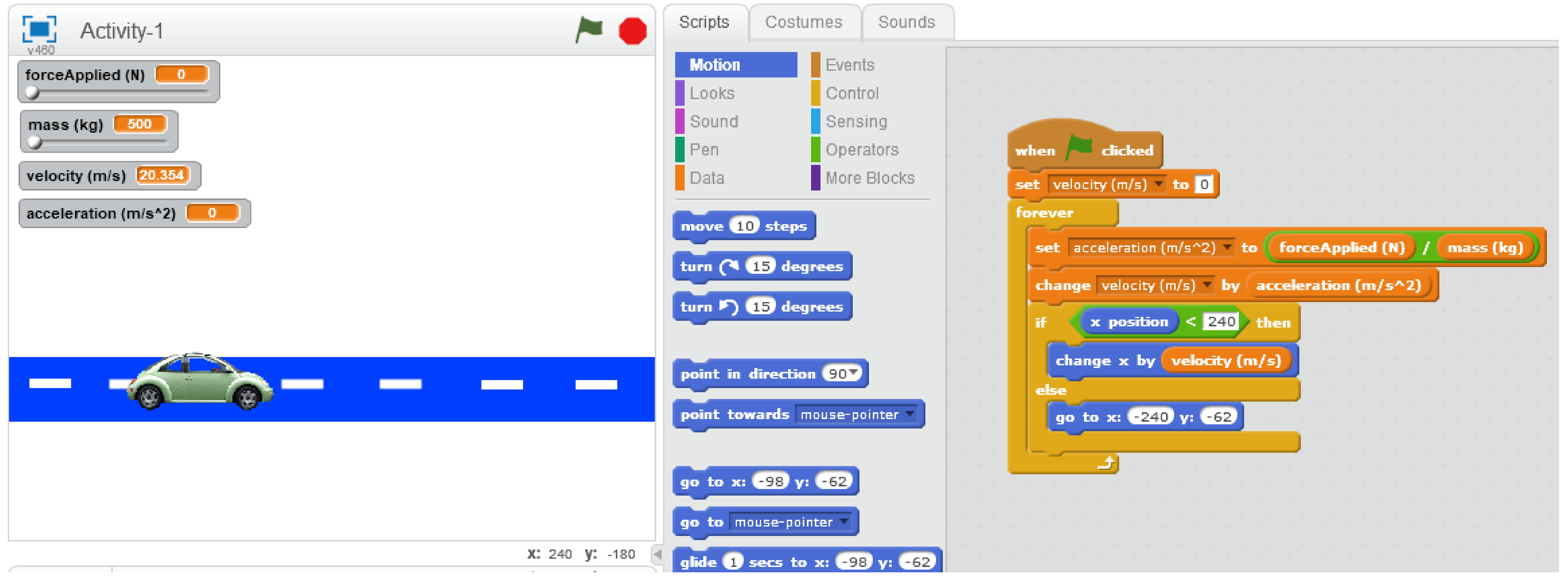

Figure 1. Screenshot of the first modeling activity

Figure 2. Screenshot of the second modeling activity

Results

Table 1. Descriptive statistics for students' scores on the Force and Motion Assessment

	M	*SD*	Median	Mode	Min.	Max.	Range
Force and Motion Assess. - Pre[a]	4.01	2.17	3.5	3	0	9	9
Force and Motion Assess. - Post[a]	6.82	2.96	6	5	2	13	11
Force and Motion Assess. - Pre (logit)[b]	33.99	10.21	33.33	30.98	0.17	53.22	53.05
Force and Motion Assess. - Post (logit)[b]	45.98	10.63	43.60	40.00	25.17	68.98	43.81

Note. *N* = 82.
[a]Raw scores out of 16.
[b]Scaled to 1-100.

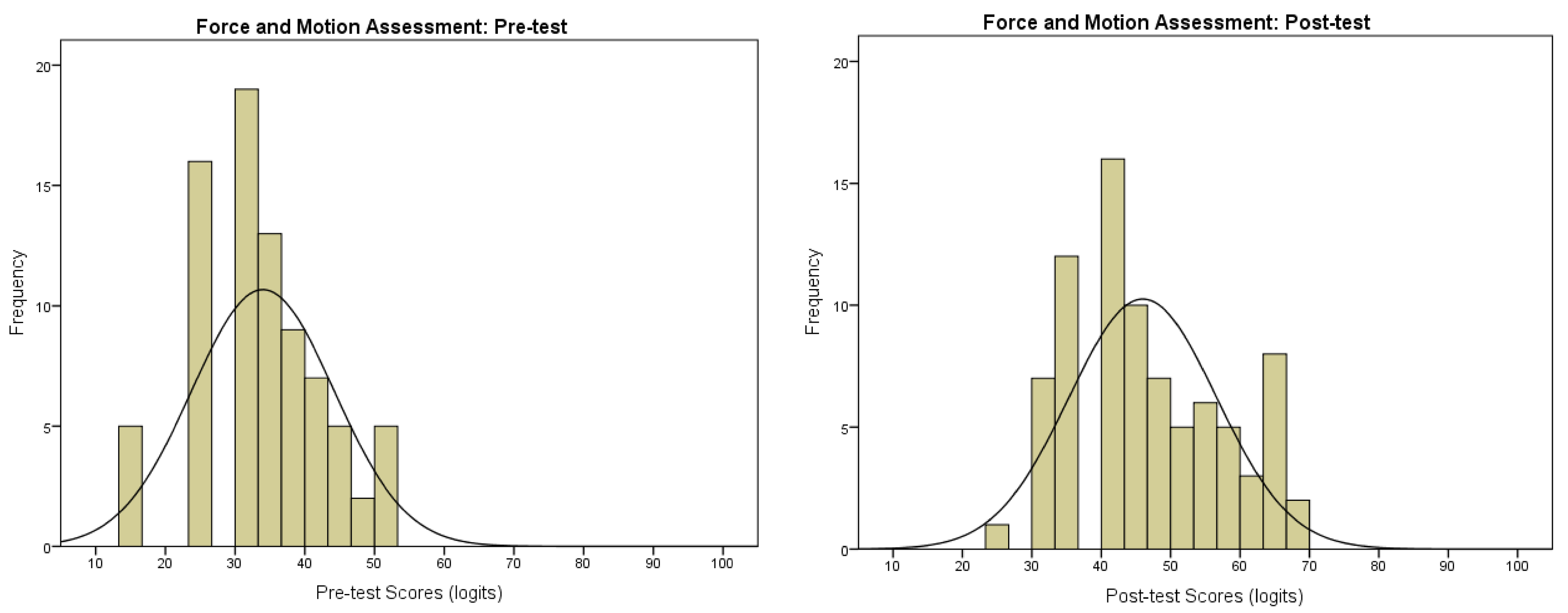

Figure 3. Histograms of the students' pre- and post-test scores

Table 2. Results of the paired-samples t-test analysis comparing students' pre- and post-test scores on the Force and Motion Assessment

	Pre-test		Post-test			
	M	*SD*	*M*	*SD*	*t* (81)	Cohen's *d*
Force and Motion Assess. (logit)[a]	33.99	10.21	45.98	10.63	9.26***	1.02

Note. *N* = 82.
[a]Scaled to 1-100.
$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$, two-tailed.

Table 3. Results of the paired-samples t-test analysis comparing students' pre- and post-test scores on the Force and Motion Assessment by gender

	Pre-test		Post-test				
	M	*SD*	*M*	*SD*	*t*	df	Cohen's *d*
Male							
Force and Motion Assess. (logit)[a]	36.29	9.79	46.40	11.02	5.89***	43	0.89
Female							
Force and Motion Assess. (logit)[a]	31.33	10.17	45.49	10.29	7.35***	37	1.19

Note. *n* = 44 for male, *n* = 38 for female.
[a]Scaled to 1-100.
$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$, two-tailed.

Table 4. Themes from student interview responses

Conceptual understanding of the Newton's First Law of Motion	"Even though **you don't apply any force**, it can continue to go but **its speed will be the same**. It will not stop because there is no friction."
Conceptual understanding of the Newton's Second Law of Motion	"The force applied it would make a big difference even though **a little bit more force applied**. Like even if it goes from like 5 to 7, it would still make a big change. You know it **will go even faster and faster.**"
Conceptual understanding of acceleration	"I also understood better how acceleration and velocity related to each other, you know if you have **high acceleration** it **will become faster after a few seconds**, if it has **less acceleration it will take more to go fast**."

Discussion

- Significant conceptual learning gains on force and motion concepts.
- Students engaged in constructing and experimenting with multiple representations.
- Affordances of simulation-based models were present: dynamic and generative dimensions of modeling.
- No differential impact of the learning activities based on gender.
- Limited conceptual understanding even after the intervention: need more time in the classroom for modeling activities to address the persistent alternative conceptions.

References

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