HISD | Research and Accountability
ANALYZING DATA. MEASURING PERFORMANCE.

EVALUATION REPORT
BUREAU OF PROGRAM EVALUATION
Volume 8, Issue 1, May 2014

The effect of the New Digital Energy game on science interests, attitudes, and knowledge, 2013–2014

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During the 2013–2014 academic year, 647 elementary, middle, and high-school students participated in the New Digital Energy Game (NDE) game in the Houston Independent School District (HISD). This is the fourth year that NDE has been implemented in HISD. The game was designed to enrich students' science experiences in order to stimulate their interests to pursue science energy careers. The game was funded by Chevron Corporation and developed by Tietronix, Inc. Paired t-test analysis yielded a sample of 382 elementary (28%), middle (61%), and high (11%) school students. Based on a 4-point Likert-type scale, the majority of students at each level indicated either no change or a slight to moderate positive change in their science interests and attitudes from pre- to post-tests. The majority of elementary, middle, and high-school students showed a loss in their science knowledge assessment scores, comparing before and after game participation results. There was a positive relationship between post-interests in science and post-attitudes about science following game participation. Propensity score, nearest neighbor matching yielded slightly lower 2014 Stanford 10 science performance of NDE students compared to a similar student group, suggesting no positive benefit of the game using this measure.

Background

Much attention has been devoted toward understanding computer games and their educational benefits to students. Computer games that provide instruction have the potential to stimulate the academic environment and increase students' awareness and knowledge of phenomenon to solve problems (Honey & Hilton, 2010; Jones, 1996; Mundie, 2011; Owston, 2009; Yang, Kun, & Chein, 2010). "Electronic gaming may be one way to engage students in critical thinking necessary to apply subject matter to "real-life" experiences" (Curriculum Review, p. 10). Digital games may encourage students to ask unanswered questions and teach them to use problem-solving techniques.

Brendzel (2004) pointed out that "games provide a natural motivation" (p. 32) to apply good teaching strategies to help build science concepts. Contest can further stimulate students' drive to compete, which may improve comprehension in a format that may be interesting to students. Interested students are more engaged in activities that they value (Bulunuz & Jarret, 2009). Ogunkola (2011) found that increased attitudes and interest in an activity is correlated with good study habits and engagement in school. Disengaged students are more likely to have poor attendance and more likely to drop out of school (Balfanz, Herzog, & Mac Iver, 2006).

The New Digital Energy (NDE) game focused on increasing students' understanding of science energy concepts. Game tasks accommodated all student academic levels by combining strategy, construction, and game management, and requiring that players build energy companies and gain dominant market share to meet the needs of U.S. cities. Students played as teams against artificial intelligence, competing across three levels of difficulty. Variations in difficulty were incorporated into lessons that students had to master to open options within the game. Lessons and questions prompted students to game-play decisions that required understanding of physics, chemistry, earth science, and math concepts.

To that end, this study measured the effects of the NDE game on students' acquisition of science

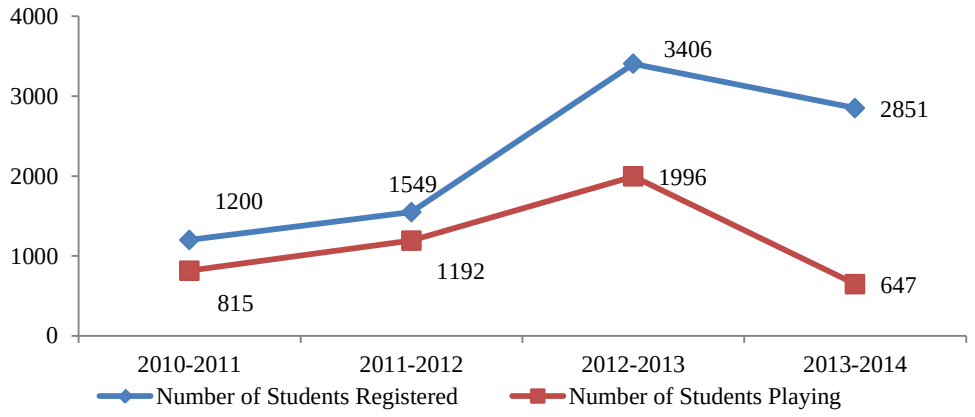

Figure 1. Number of students who registered and played the NDE game, 2010–2011 through 2013–2014

knowledge and science achievement. In addition, the study assessed the effects of the game toward increasing students' interests and attitudes in science.

Methods

All Study Participants

All HISD elementary, middle, and high-school science teachers were invited to recruit students to participate in the NDE game during the fall of 2014. Teachers were required to register and sign a letter of commitment to participate. **Figure 1** presents the number of students who registered along with the number of students who played the game over the past four academic years. Twenty-two schools and 29 teachers were represented in the 2012–2013 data; whereas, seven elementary and nine secondary schools (eight middle schools and one high school) were represented in the 2013–2014 data. Students playing the game dropped by 20.6 percent from the 2012–2013 to the 2013–2014 academic year. There was also a drop in registration (-16.3%) and participation (-67.6%), from the previous to the current academic year.

Student Sample

The study sample consisted of 107 elementary, 233 secondary, and 41 high school students who completed the four instruments (pre- and post-science energy knowledge assessments along with pre- and post-science interest/attitude surveys). Students in the matched sample were enrolled at seven elementary schools, eight middle schools, and one high school. **Table 1** presents demographic characteristics of the matched student sample. The majority of students were male (between 52.8% and 76.0%) and economically disadvantaged (between 78.5% and 87.0%). The highest proportion of at-risk students was at the elementary level (58.3%) compared to the lowest percentage at the middle-school level (23.6%) There were nearly twice as many limited English proficient (LEP) students at the elementary level than at the middle-school level (34.3% vs. 17.2%). High-school students were only 4.9% LEP. Comparatively, the District had a higher percentage of at-risk students (68.7%) and a lower percentage of G/T students (15.6%) than the NDE student sample at all levels (PEIMS, 2013–2014).

Measures and Variables

Students were administered four web-based surveys accessed at the game site. The instruments included a 10-item science interest survey, a 10-item science attitudes survey, and a 17-item multiple-choice science energy assessment using a pre- and post-test design. The survey items measuring interests and attitudes had good internal consistency, with a Cronbach alpha coefficient of .81 and .86, respectively. While students were encouraged to complete the instruments, no incentives were offered for completion.

Table 1: Profile of NDE Student Sample by School Level, 2014

	Elem (n = 108)	**Middle** (n = 233)	**High** (n = 41)	**HISD**
Gender	**%**	**%**	**%**	**%**
Male	52.8	76.0	56.1	51.0
Female	47.2	24.0	43.9	49.0
Eco. Disadv.	87.0	78.5	82.1	80.4
At Risk	58.3	23.6	43.9	68.7
G/T	21.3	33.9	31.7	15.6
LEP	34.3	17.2	4.9	29.5
Spec. Ed.	8.3	1.7	0.0	7.7

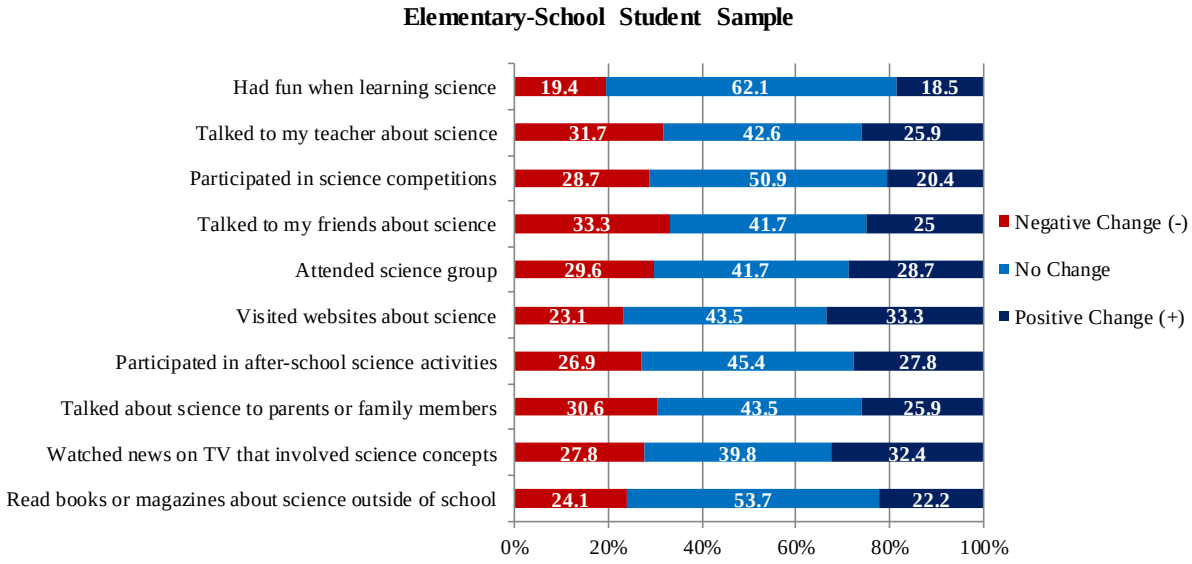

Figure 2: Percentage of elementary-school students whose interest in science ratings before and after participation in NDE showed a positive change (1 to 3 points), no change (0 points), or a negative change (-1 to -3 points) based on 4-point Likert-type scale

Interests were rated using a Likert-type scale: very often-4; regularly-3; sometimes- 2; and never or hardly ever- 1. Attitudes were rated strongly agree-4; agree-3, disagree-2, and strongly disagree-1.

The percentage of students whose ratings increased by one to three points, did not change, or decreased by one to three points from pre- to post-test was analyzed using IBM SPSS. Comments about students' experiences were summarized. Descriptive statistics and correlation analysis was conducted between the measures. Propensity score matching was used to estimate the probability of being exposed to treatment given a set of observed variables. Propensity score matching is a common practice in social science to make causal inferences based on observational data (Cohen, 1988). NDE students who were included in the "study sample" were used in the propensity score matching. Economic status, gender, grade level, special education program status, and current 2014 Stanford reading normal curve equivalent scores were the control variables.

What was the impact of the NDE game on students' science interests and attitudes?

Figure 2 and **Table 2** depict interest and attitude survey results of the elementary student sample before and after participation in the NDE game in 2014. The interest items that showed the highest percentage of "positive change" were "visited websites about science" and "watched news on TV that involved science concepts" (33.3% and 32.4%, respectively).

Table 2. Science Attitudes of Elementary-School Student Sample Before and After Participation in the NDE game, 2014

	Positive Change (+)	No Change	Negative Change (-)
	%	%	%
I am interested in learning more science.	20.6	50.5	29.0
Science will help me become successful.	17.1	60.0	22.9
I like studying science.	22.8	56.4	20.8
A science energy game will help me learn difficult science theories that I may not understand without seeing it in the game.	22.4	46.7	30.8
Studying science is worthwhile because it will improve my career opportunities.	23.1	48.1	28.7
Making an effort to study science is worth it because it will help me get into college.	17.8	55.1	27.1
I study science because I know it is useful to me.	11.1	58.3	30.6
I would like to have a career involving science.	21.9	46.7	31.4

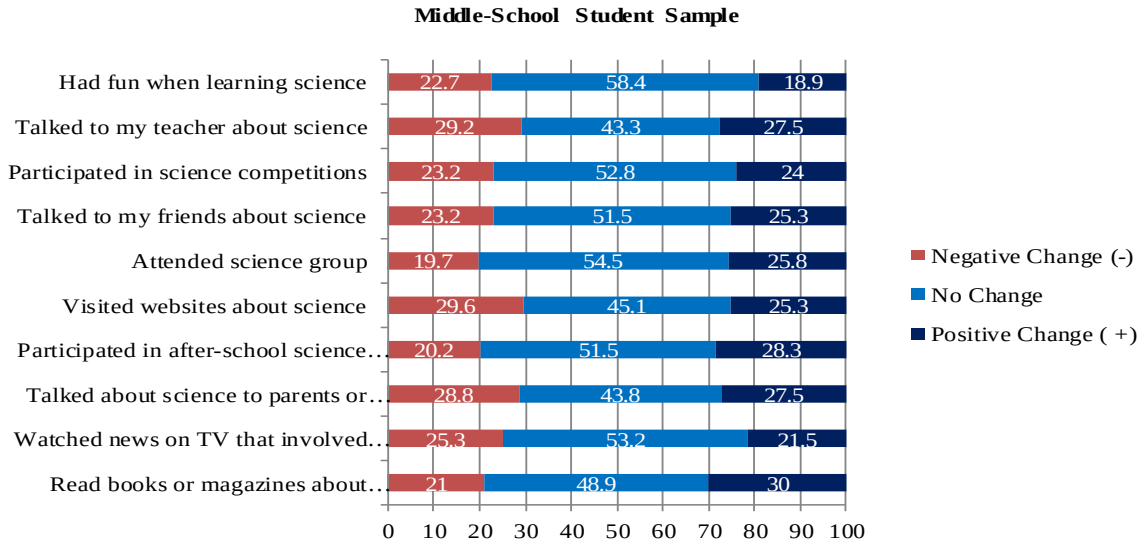

Figure 3: Percentage of middle-school students whose interest in science ratings before and after participation in NDE showed a positive change (1 to 3 points), no change (0 points), or a negative change (-1 to -3 points) based on 4-point Likert-type scale

"No change" was most likely on the item "had fun when learning science" (62.1%). The highest percentage of "negative change" in ratings was on the item "talked to my friends about science".

Regarding their attitudes about science, the item that reflected the highest percentage of "positive change" was "study science is worthwhile because it will improve my career opportunities" (23.1%). "Science will help me be more successful" showed the highest percentage of "no change" (60.0%); whereas, the item that showed the highest percentage of "negative change" was that "I would like to have a career involving science" (31.4%).

Science interest and attitude results of middle-school students before and after participation in the game can be found in **Figure 3** and **Table 3**. The science interest item that reflected the highest percentage of "positive change" from pre- to post-test was "reading books or magazines about science outside of school" (30.0%) and "participating in afterschool science activities" (28.3%) (Figure 3).

Relative to attitudes (Table 3), the middle-school students were more likely to express "positive change" on the item "I like studying science" (20.5%). At the same time, the highest percentage of "no change" was on "making an effort to study science is worth it because it will help me get into college" (82.9%).

Table 3. Science Attitudes of Middle-School Student Sample Before and After Participation in the NDE game, 2014

	Positive Change (+)	**No Change**	**Negative Change (-)**
	%	**%**	**%**
I am interested in learning more science.	14.6	48.8	36.6
Science will help me become successful.	14.6	61.0	24.4
I like studying science.	20.5	51.3	28.2
A science energy game will help me learn difficult science theories that I may not understand without seeing it in the game.	14.6	43.9	41.5
Studying science is worthwhile because it will improve my career opportunities.	10.3	71.8	17.9
Making an effort to study science is worth it because it will help me get into college.	17.1	82.9	31.7
I study science because I know it is useful to me.	12.2	48.8	39.0
I would like to have a career involving science.	10.0	57.5	32.5

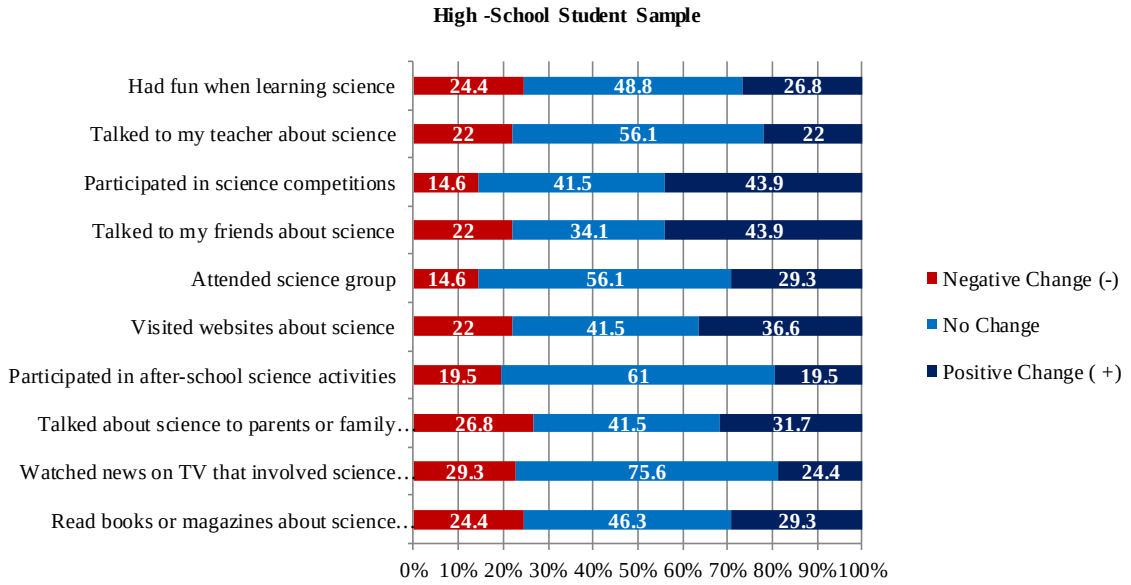

Figure 4: Percentage of high-school students whose interest in science ratings before and after participation in NDE showed a positive change (1 to 3 points), no change (0 points), or a negative change (-1 to -3 points) based on 4-point Likert-type scale

"Negative change" was most evident on "a science energy game will help me learn difficult science theories that I may not understand without seeing it in the game" (41.5%).

The results of the high-school student sample regarding their interests and attitudes about science are shown in **Figure 4** and **Table 4**, respectively. The science interest item that showed the highest percentage of "positive change" was "participated in science competitions" and "talked to my friends about science" (43.9%). "No change" was most evident on the item "watched news on TV that involved science concepts" (75.6%). "Negative change" was also more likely on this item (29.3%) (Figure 4).

"Positive change" in attitudes about science for high-school students was highest on the item "I study science because I know it is useful to me" (27.1%) (Table 4). The highest percentage of students expressed "no change" on the item that "making an effort to study science is worth it because it will help me get into college (59.4%). At the same time, the highest percentage of "negative change" was reflected on "a science energy game will help me learn difficult science theories that I may not understand without seeing it in the game" (32.6%).

Table 4. Science Attitudes of High-School Student Sample Before and After Participation in the NDE game, 2014

	Positive Change (+)	**No Change**	**Negative Change (-)**
	%	**%**	**%**
I am interested in learning more science.	22.3	48.1	29.6
Science will help me become successful.	24.7	53.7	21.6
I like studying science.	24.2	54.3	21.5
A science energy game will help me learn difficult science theories that I may not understand without seeing it in the game.	23.5	43.9	32.6
Studying science is worthwhile because it will improve my career opportunities.	22.0	50.4	27.6
Making an effort to study science is worth it because it will help me get into college.	16.6	59.4	24.0
I study science because I know it is useful to me.	27.1	46.3	26.6
I would like to have a career involving science.	20.6	53.9	25.4

Table 5. Science Knowledge Assessment Raw Score Results of the Student Sample Before and After Participation in the NDE game, 2014

	Gain (+)					**Loss (-)**					**No Diff.**	
	Raw Score					Raw Score						
	n	%	Min	Max	Mean	n	%	Min	Max	Mean	n	%
Elementary (n=108)	31	28.7	5.9	29.4	10.6	66	61.1	5.9	47.1	16.4	**11**	10.2
Middle (n=233)	89	38.2	5.9	41.2	13.8	100	42.9	5.9	52.9	13.2	44	18.9
High (n=41)	11	26.8	5.9	17.7	10.7	26	63.4	5.9	52.9	17.9	4	9.8
Total (n=382)	131	34.3	5.9	41.2	12.8	192	50.3	5.9	52.9	15.0	59	15.4

What was the effect of the NDE game on students' science knowledge?

Table 5 shows the mean "gain", "loss", and "no difference" in the science knowledge raw scores from pre- to post-assessment of the student sample. The minimum and maximum number of points that students gained or lost along with the number and percentage of students who had gains, losses, and showed no difference in their science knowledge assessment raw scores from pre- to post-assessment are presented.

Middle school students achieved the highest mean "gain" in their raw score on the knowledge assessment (13.8 points). Elementary and high-school students attained comparable gains in their raw scores (10.6 and 10.7 points, respectively). High-school students attained the highest mean "loss" in their raw score on the assessment over time. The highest percentage of the middle-school student sample had "no difference" in their science assessment raw score before and after participation in the game. Over two-thirds of the high and elementary-school students showed either a loss or no change on the assessment. Only one-third of the students overall showed any gain in their knowledge assessment raw score.

What were the associations between science interests, attitudes, and science assessment results before and after participation in the NDE game?

Table 6 depicts means and standard deviations along with intercorrelations of the measures for the elementary-school student sample. There were slight decreases in their mean interest (-.08) and attitude ratings (-.13) as well as a moderate decrease in their mean science knowledge assessment scores (-6.97 points) from pre- to posttest. Other notable findings included a positive association between elementary-school students' post-interests, post-attitudes, and post-science knowledge assessment results. In other words, as elementary students' interests in science increased, their attitudes and science knowledge assessment scores increased after participation in the game. Pre- and post-attitudes as well as pre-knowledge intercorrelations with post-knowledge were highly statistically significant at $p<.01$.

Table 6, Summary of Intercorrelations, Means, and Standard Deviations for Scores on the Pre- and Post-Science Interest, Attitude, and Knowledge Measures for the Elementary Student Sample, 2014

	1	**2**	**3**	**4**	**5**	**6**
1. Pre-Interest	-	.622**	.560**	.390**	-.048	.006
2. Post-Interest	.622**	-	.520**	.656**	.100	.120
3. Pre-Attitude	.560**	.520**	-	.628**	.113	.292**
4. Post-Attitude	.390**	.656**	.628**	-	.176	.311**
5. Pre-Knowledge	-.048	.100	.113	.176	-	.625**
6. Post-Knowledge	.006	.120	.292**	.311**	.625**	-
M	2.66	2.58	3.10	2.97	45.10	38.13
SD	.58	.65	.63	.68	15.98	18.11

**p<.01

Table 7. Summary of Intercorrelations, Means, and Standard Deviations for Scores on the Pre- and Post-Science Interest, Attitude, and Knowledge Measures for the Middle-School Student Sample, 2014

	1	2	3	4	5	6
1. Pre-Interest	-	.595**	.525**	.403**	.030	.020
2. Post-Interest	.595**	-	.456**	.629**	-.011	.042
3. Pre-Attitude	.525**	.456**	-	.568**	.072	.037
4. Post-Attitude	.403**	.629**	.568**	-	.082	.110
5. Pre-Knowledge	.030	-.011	.072	.082	-	.690**
6. Post-Knowledge	.020	.042	.037	.110	.690**	-
M	2.37	2.41	3.00	2.90	56.22	55.79
SD	.56	.59	.67	.77	17.10	18.95

**p < .01

Table 8. Summary of Intercorrelations, Means, and Standard Deviations for Scores on the Pre- and Post-Science Interest, Attitude, and Knowledge Measures for the High-School Student Sample, 2014

	1	2	3	4	5	6
1. Pre-Interest	-	.409**	.371*	.232	.299	.235
2. Post-Interest	.409**	-	.309*	.314*	.113	-.154
3. Pre-Attitude	.371*	.309*	-	.501**	.074	.063
4. Post-Attitude	.232	.314*	.501**	-	.099	.210
5. Pre-Knowledge	.299	.113	.074	.099	-	.677**
6. Post-Knowledge	.235	-.154	.063	.210	.677**	-
M	2.63	2.76	3.11	2.82	65.14	56.67
SD	.64	.63	.63	.67	18.62	23.00

*p < .05; **p < .01

Middle-school students' results can be found in **Table 7**. There was a slight increase in their mean interests rating (+.04) from pre- to post-survey. However, there were slight decreases in their mean attitudes rating (-.10) and mean science knowledge assessment score over the same time period (-.43 points). Regarding the post-survey measures, as post-interests in science increased ($p < .01$), post-attitudes ($p < .01$), and post-science knowledge increased.

Data on high-school students is shown in **Table 8**. The mean interests rating increased slightly (+.13) from pre- to post-test, while the mean attitudes rating decreased (-.29) over the same time period. There was a moderate decrease in students' mean science knowledge assessment score (-8.47) before and after participation in the game. As post-interests in science increased ($p <. .05$), post-attitudes increased ($p < .05$), and post-science knowledge decreased.

What was the effect of the NDE game on science achievement?

Propensity score, nearest neighbor matching was used to determine the effect of the NDE program on students' 2014 Stanford science NCE scores (See **Appendix A**). The statistical model used in the analysis controlled for economic status, grade level, gender, special education program status, and 2014 Stanford 10 reading NCE scores. Bias analysis was conducted and yielded a comparison sample where the treated and untreated shared the same characteristics, which means that the selection bias had been mitigated in the "new" sample (Austin, Grootendorst, and Anderson, 2007). Out of the 272 NDE students in the initial sample, *Stata* selected 270 students for the model. Out of the 53,627 students in the comparison group, *Stata* selected 52,404 students for the model. Prior to controlling for these variables, the

NDE students had a higher science score than the control group (58.1 vs. 52.6 NCEs). Propensity score matching yielded slightly lower science performance due to participation in the program compared to students who did not participate in the program (-1.3 NCEs). Although the difference was not statistically significant, the model suggested that the NDE program did not have a positive effect on students' Stanford science NCE scores.

Discussion

The New Digital Energy game was designed to increase student's understanding of science energy concepts by introducing game construction and management strategies. Students worked as teams to build energy companies, gain dominant market share, and meet the needs of cities throughout the United States. Students played against artificial intelligence to answer challenging questions about science energy. An objective of the game was to increase students' interests and attitudes about science as they increased their knowledge of science energy concepts.

There were several limitations to the study. First, given the team format, the study lacked data on actual time spent by individual students playing the game. This could have affected students' experiences gaining science energy knowledge and influenced their interests and attitudes about science at post-test. Another limitation was the lack of a comparison group to assess the impact of the game on students' interests and attitudes. While a pre- post-test design provided an alternative method for comparing students, threats to validity could still exist relative to knowing whether other external factors influenced the changes in student outcomes over time (Boyd, 2002). In consideration of these threats, propensity score matching was used to reduce bias and assess whether participation in the game had an effect on students' science achievement while controlling for key demographic characteristics. No benefit was observed in student's science performance on the 2014 Stanford 10 achievement test. Finally, the lack of data at the four data collection points on all students who played the game resulted in substantial attrition. (The number of students who played the game was substantially lower than the number of students who initially registered (647 out of 2851 students). Even less students were included in the final analysis of the data (382). The recruitment process relied on teacher commitment, which may have contributed to attrition of the initial group of student participants.

The majority of elementary, middle, and high-school students showed either no change or a slight to moderate positive change in their science interests and attitudes from pre- to post-tests. Moreover, the majority of students at all levels had a loss in their science knowledge assessment scores over the same time period. Among the most notable positive findings were as students' interests in science increased after participation in the game, their attitudes about science also increased after the game. Also, there was a positive association between elementary and middle-school students' post-interests in science and post-science knowledge. However, for high-school students, as post-interests increased, post-science knowledge decreased. This finding seems inconsistent with the expectation that a positive relationship should exist between interests and achievement (Brendzel, 2004). Moreover, previous year results were consistently positive (Holmes, 2013). While each year, a different student sample may have participated in the program, a recommendation is to further explore students' perceptions about the game in more detail. This could be done through focus groups or one-on-one interviews with students who have participated in the game over the past four years. Information gathered from students could be incorporated in future game development. Another recommendation is to reconsider strategies on successful recruitment of science teachers and students from more HISD schools. Finally, while evidence of improvements in students' science knowledge was not evident in this study, what may be more important is that students were exposed to science material needed to enhance their understanding of science concepts (Wainwright & Linebarger, 2006). These experiences may be valuable to students who, otherwise, could not afford them.

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Appendix A

Propensity Score Matching Results

	Treated (n = 270)	**Controls (52,404)**			
	Mean Science NCE	**Mean Science NCE**	**Difference**	**S.E.**	**T-stat**
Unmatched	**58.1**	**52.6**	**55.6**	**13.93**	**3.99**
Matched	**58.1**	**59.4**	**-13.1**	**18.11**	**-.072**