Title: New Digital Energy Game, the Use of Games to Influence Attitudes, Interests, and Student Achievement in Science

Author: Venita Holmes, Dr.P.H.

Date: May 31, 2012

Purpose: To assess how the use of games contributes to students' science learning, interests, and attitudes about science.

Methodology: The study sample was middle and high-school students in a large urban school district. A total of 1191 students participated in the game. The majority of students were Hispanic females of low socio-economic backgrounds. Students were recruited by science teachers at their schools. A mixed-method, pre-posttest design was used to measure students' science knowledge, attitudes, and interests. The instruments were piloted in the previous year with a comparable student group, and were found to be reliable measures. The instruments were distributed, using a web-based format, to students in their science classes. Items on the science test were developed based on state standards. Students were offered incentives to participate in the game.

Results: Findings from a paired sample of 391students revealed a statistically significant increase in the number of science test items answered correctly from pre- to posttests. Eta squared results indicated a moderate effect size. There was also a statistically significant increase in the overall mean interest rating, but a decrease in the mean attitude rating over the study period. Pearson's r revealed a strong, positive correlation between students' interests and attitudes about science.

Conclusions: There was evidence that, as students' interests in science increased, their attitudes about science increased. Moreover, as students' pre- interests and attitudes about science increased, their post science assessment scores increased.

Recommendations: There were limitations to the study, including the lack of a comparison group who did not participate in the game. Nevertheless, the findings suggest immediate benefits in the use of games to improve middle and high-school students' science performance. Future studies might investigate the long-term impact of the game on students' science achievement and career pathways.
Additional data: (There are 7 tables and graphs included in the paper.)

Chevron expanded its funding of the New Digital Energy game (NDE) to cover a three-year period (2010–2013). This collaboration with Tietronix Software, Inc. and a large school district in Houston, Texas led to the development of a computer game designed to transform the learning experience of middle and high-school students in science. NDE combines aspects of strategy, construction, and game management, requiring players to build energy companies, gain dominant market share and meet the needs of cities throughout the United States. Cooperative teams of students play against artificial intelligence, competing across three levels of difficulty. Variations in difficulty are incorporated into lessons that students must master in order to open options within the game. Lessons and questions are designed to lead players to game-play decisions that require understanding of physics, chemistry, earth science, and math concepts. A meta-site is available outside of game play for students to supplement their learning and success for subsequent game play. Lessons are crafted within the game to encourage learning through inquiry. Lessons are aligned to the Texas Essential Knowledge and Skills standards (TEKS) (NDE, correspondence, 2011). The program included field trips to the Ocean Star Offshore Drilling Rig & Museum in Galveston and the Houston Museum of Natural Sciences' WEISS Energy Hall. Students were awarded prizes for high scores and participation in the game.

Study Sample and Methods

All middle and high school science teachers were invited to have their students participate in the NDE game. Students played the game during the fall semester for approximately 3 months. **Figure 1** shows a 29.1 percent increase in the number of students who registered for the game and a 45.1 percent increase in the number of students who played the game over the past two years. Sixteen schools and 26 teachers were represented in the 2011–2012 data among 85 middle and high schools invited to participate.

Students' interests and attitudes concerning science were measured using a web-based pre- and post survey. Tietronix Software, Inc. worked collaboratively with the Secondary Curriculum, Instruction, and Assessment Department to develop the instrument. Students' knowledge of science concepts were also measured using a pre-post assessment design. Students were provided electronic links to the instruments on the game Web site and through their science teachers. While the level of participation in the game could have influenced students' interests, attitudes, and science energy knowledge, participation levels were not captured by Tietronix Software, Inc. to maintain students' anonymity and confidentiality.

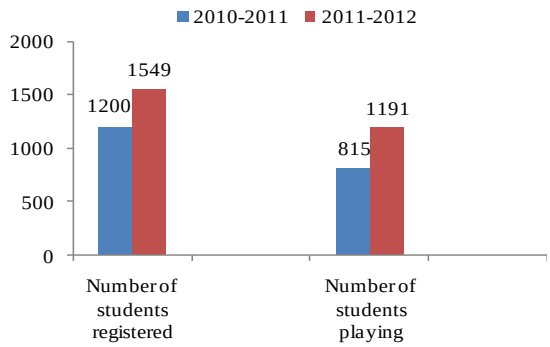

Figure 1. Number of all students who registered and participated in the NDE in game, past two academic years.

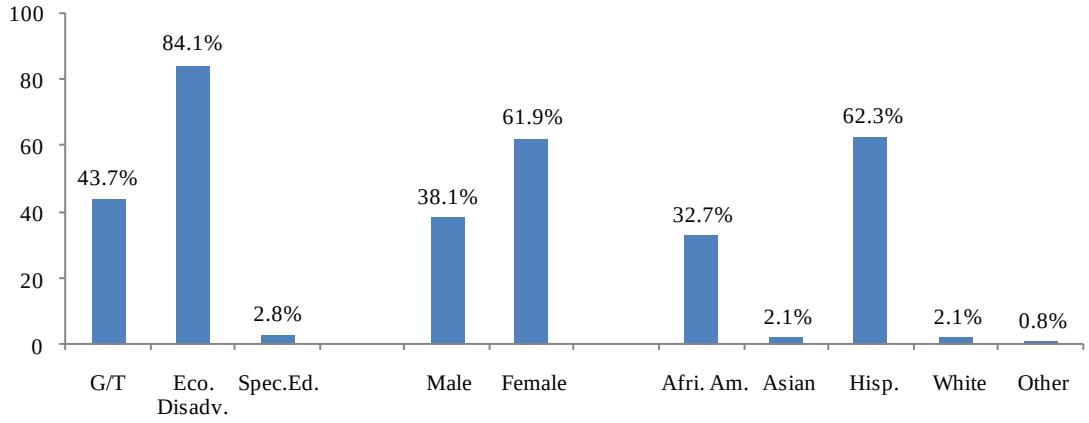

Figure 2. Demographic characteristics of NDE game matched sample, 2011-2012
Note: Sample size = 391

Results of a matched-paired sample of 391 students who completed the four measures (pre- and post science energy knowledge assessments as well as the pre- and post interest/attitude surveys) were extracted from the data for analysis. Students in the matched sample were enrolled at seven middle and two high schools. **Figure 2** presents demographic characteristics of the matched student sample. The majority of students were economically disadvantaged (84.1 percent), male (61.9 percent), and Hispanic (62.3 percent). In addition, 43.7 percent of the sample was enrolled in gifted and talented programs (G/T), while 2.8 percent received special education services. Representation of Hispanic students in the sample was comparable to the districtwide Hispanic student population in the current year (62.4 percent). African American students were overrepresented in the NDE sample compared to the district wide percentage (32.7 vs. 25.1 percent). G/T and special education students were also more prevalent in the district than in the study sample (15.1 and 7.8 percent respectively) (PEIMS, 2011–2012).

Descriptive statistics, including means and standard deviations, were calculated based on student responses using IBM SPSS software**.** Paired sample data measuring the percent change in students' raw scores on the knowledge-based science energy assessment and the percent change in students' level of agreement (strongly agree or agree) with survey items measuring interest and attitudes were reported. Pearson correlation coefficient measured the association between pre-post science energy knowledge and pre- and post interest/attitudes ($p<.05$).

Background

Over the past decade, educators have sought innovative approaches to strengthen student achievement in science. The National Science Foundation (2008) found that computer games enhance the educational experience of students, partly due to the multifaceted process required to learn science (Honey and Hilton, 2010). Mundie (2011) maintains that "Technology has the potential to help reinvent the education process, and excite and inspire young learners to embrace science, math and technology" (p.1). In efforts to add to the body of knowledge, researchers have discovered that, "the best educational activities connect not only to important concepts but also to students' interests and passions" (Games for Learning Institute, 2011, p.1).

Computer games are inherently interactive, and have, increasingly, become a new and innovative approach to teaching and learning science as they capture the attention of youth. In addition, computer games allow students to be transported into another reality and engage in activities that simulate the real world while exploring natural phenomena that cannot be directly observed (Games Research, 2011; Mundie, 2011).

Table 1: Change in Raw Scores of Students on Science Assessment on Pretest Compared to Posttest, 2011-2012

	Positive Change		No Change		Negative Change		Total
Grade	**n**	**%**	**n**	**%**	**n**	**%**	N
6	84	52.2†	22	13.7	55	34.2	161
7	24	39.3	10	16.4	27	44.3	61
8	42	43.7	17	17.7	37	38.5	96
9	14	42.4	4	12.1	15	45.5	33
10	12	48.0	4	16.0	9	36.0	25
11	5	55.6†	1	11.1	3	33.3	9
12^{th}	2	83.3†	2	33.3	2	33.3	6
All Grades	**183**	**46.8**	**60**	**15.3**	**148**	**37.9**	**391**

Note: †Represents the majority positive change at specified grade level

Research was conducted in HISD on the first year of implementation of the NDE program. The study found an increase in students' interest and attitudes in science (Holmes, 2011). While there continue to be gaps in the research on which gaming features contribute to student learning, this study builds on the body of evidence relative to the effectiveness of games toward enhancing students' interest and attitudes about science and their ability to learn science concepts through games.

What was the impact of the NDE game on students' acquisition of science energy knowledge?

Table 1 presents the number and percent change in the raw scores of students on an assessment that measured science energy knowledge. Results reflect positive change, no change, and negative change scores by grade level between pre- and post assessments. The overall percentage of students with positive change scores was 46.8 percent compared to 15.3 percent of students with no change in their assessment scores. The percentage of students with positive change scores ranged from 39.3 percent to 83.3 percent at various grade levels. Table 1 also shows that the majority of 6^{th}, 11^{th}, and 12^{th} -grade students showed positive changes in their test scores.

A paired t-test was conducted based on the percent of items that students answered correct on the pre- and post science energy assessment. The analysis showed a statistically significant increase in the percent of items correct from pretest (M=40.35, SD=19.8) to posttest (M=45.40 and SD=22.01), t(390)=4.35, p=.000 (two-tailed). The mean difference was 5.05. The 95% confidence interval ranged from 2.765 to 7.338. The eta squared statistic (.05) indicated a moderate effect size of the program, based on science assessment performance.

To what extent was students' interest in science influenced by game participation?

A Likert-type scale was used to rate the frequency that students engaged in activities conceptualized as measuring interest in science before and after participating in the game. The scale used in the survey was: very often-4; regularly-3; sometimes-2; and never or hardly ever-1. The results of 391 students (33% response rate for the paired sample) are included in the analysis. Ratings of very often and regularly were combined to show the percent change from pre- to post survey. The results are shown in **Figure 3** (page 4).

It is apparent in Figure 3 that the highest percent change in students responding very often or regularly to interest-related items was participation in science competitions (112.2%) and talking to parents or family members about science (95.4%). The percent of students indicated very often or regularly from pre- to post survey increased by more than 50 percent on the following items: talked to their friends about science (92.3 percent), attended science groups (78.4 percent), and participated in after-school science activities (65.9 percent).

A paired t-test analysis showed a statistically significant increase in the overall mean interest rating from pre survey (M=2.27, SD=.67) to post survey (M=2.37, SD=.73, t(390)=3.41, p<.001). The 95% CI [.041, .241] provides additional evidence of a significant difference in how students rated frequency of participation on items related to interest in science before and after the game. The eta squared statistic (.03) indicated a small effect of the program on students' interest in science.

To what extent were students' attitudes about science influenced by the NDE game?

Survey items measuring students' attitudes about science were based on the following categories: strongly agree-4, agree-3, disagree-2, and strongly disagree-1. The same 391 students whose results were used to measure their interest were also used to measure their attitudes about science from pre to post survey. The findings depicting the combined

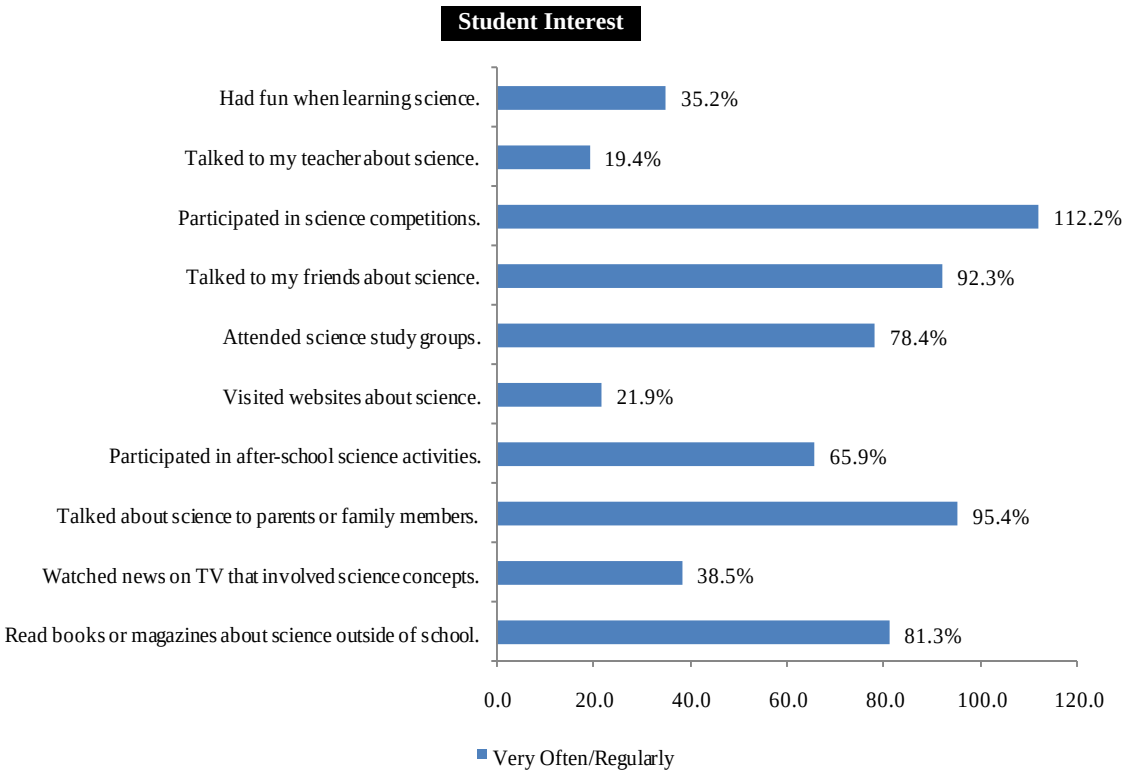

Figure 3. Percent change in student's ratings of very often or regularly on survey items measuring interest in science energy from pre to post assessment.
Note: Sample size =391

categories of strongly agree and agree, are presented in **Figure 4** (page 5).

The highest percent change in students indicating strongly agree or agree to attitude-related items were that they like to study science (49.7 percent), are interested in learning more science (46.0 percent), and would like to have a career involving energy (oil, wind, solar, nuclear, biomass, and natural gas) (45.8 percent). Students were least likely to change that they strongly agreed or agreed the game would help them learn difficult science theories that they may not understand without seeing the game (0.0 percent) and studying science is worth it because it will help them get into college (3.7 percent).

A paired t-test analysis showed a statistically significant decrease in the overall mean rating from pre survey (M=2.91, SD=.76) to the post survey (M=2.82, SD=.77, t(390)=-2.85, p<.005). The 95% CI was [-.146, -.027]. The eta squared statistic (.02) indicated a small effect on the student samples' attitudes about science after the game.

Was there an association between students' science energy knowledge, interest, and attitudes regarding science?

The relationship between students' pre- and post science energy knowledge, interest and attitudes about science were investigated using the Pearson product-moment correlation coefficient (**Table 2**) (page 5). Preliminary analysis was conducted to ensure no violation of test assumptions. Some of the most notable results were the strong positive associations between students' interest and attitudes [r=.678, n=391, p<.01]. Specifically, as students' interest in science increased, their attitudes about science increased. The results were highly statistically significant. The data also showed as pre interest and pre attitudes scores increased post assessment scores increased [r=.108, n=391, p=.034] and [r=.192, n=391, p=.000], respectively.

What were students' overall impressions of the NDE game?

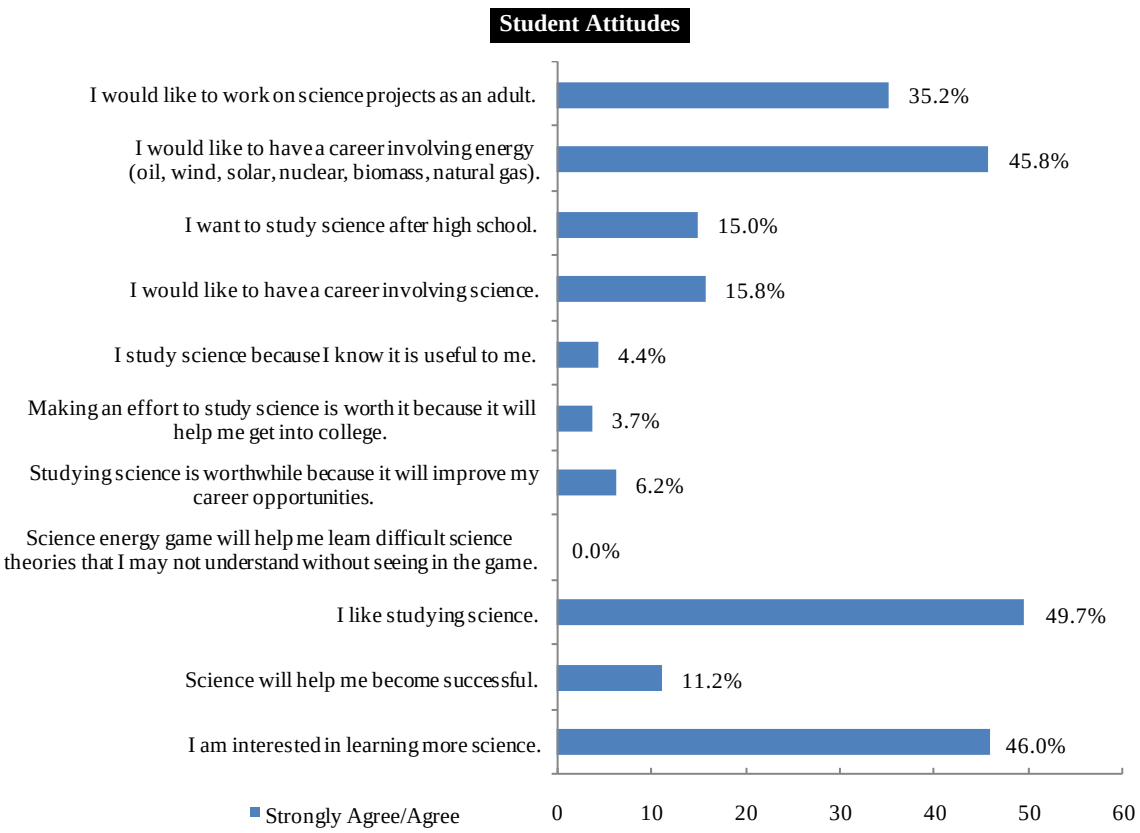

Figure 4. Percent change in student's ratings of strongly agree or agree on survey items measuring attitudes about science energy from pre to post assessment.
Note: Sample size =391

Students were asked to provide additional comments about the NDE game following participation. The open-ended responses of all students who completed the post interest /attitudes survey were included in the analysis. Responses were analyzed using IBM SPSS Text Analytics and the SurveyMonkey Text Analysis feature in order to triangulate emerging themes. Themes are based on comments of 158 respondents.

The most prevalent themes focused on students' positive impressions of the game (n=69). Students describe the game as "fun" (n=38), "awesome" (n=9), "interesting" (n=9), "great" (n=5), "cool" (n=4), and "amazing" (n=2). Some students mentioned that the game was "helpful" (n=15) and a learning experience. One student wrote, *"The game was very fun and helped me learn about different types of resources and which are best."* Another student wrote, "*I like it because it is educational for me to learn more things about science in the world or even everywhere I go. It's a fun game with a[n] educational twist that I would like to learn more stuff about."*

Table 2: Pearson Product-Moment Correlations Between Measures of Achievement, Interest and Attitude

Measures	**1**	**2**	**3**	**4**	**5**	**6**
Pre Science Assessment (1)	1.00					
Post Science Assessment (2)	.399**	1.00				
Pre Interest (3)	.141**	.108*	1.00			
Post Interest (4)	.005	.005	.679**	1.00		
Pre Attitude (5)	.232**	.192**	.678**	.508**	1.00	
Post Attitude (6)	.110*	.169**	.589**	.718**	.695**	1.00

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the .05 level (2-tailed)

Table 3: Teacher Perceptions Regarding the NDE Game's Impact on Instruction, 2011-2012

Since participating in the game, indicate the level of agreement that you changed your instructional practices in the following areas:	**Strongly Agree %**	**Agree %**	**Disagree %**	**Strongly Disagree %**	**n**
Assign more web-based instructional activities	25.0	50.0	25.0	0.0	8
Assign more team projects and cooperative group tasks	14.3	57.1	28.6	0.0	7
Access more websites about science concepts	12.5	75.0	12.5	0.0	8
The science game exposed my students to information that required the use of critical thinking skills.	50.0	50.0	0.0	0.0	8
Students seemed more interested in science after participating in the game.	37.5	62.5	0.0	0.0	8
I adjusted my instructional practices based on students' inquiry and feedback.	25.0	50.0	25.0	0.0	8
I used additional resources to support the concepts covered in the game.	37.9	50.0	12.5	0.0	8
Students seemed more motivated to do well in science after participating in the game.	25.0	75.0	0.0	0.0	8

Several students perceived long-term benefits of participating in the game. Some comments were: "*It is a great experience that will help me have a back up in my career. It will help me understand and become successful."* Another student wrote: "*This game has not only taught me new things about science but also taught me new things about running a business."* Students' general satisfaction was expressed by replying "*I like it*" (n=26) and "*thanks*" for allowing them to participate (n=5).

Three students noted technical problems with the game. One student commented: "*The game was very interesting, I would like to play every year. But, there are a lot of problems that need to be fixed."* Suggestions included resolving the "*glitches*" and the game "*freezing*."

What were NDE teachers' perceptions regarding the game's impact on student performance?

Of the 26 participating teachers, eleven middle and high-school teachers who had at least five students complete the pre- and post surveys and assessments were asked to provide input on the program's impact on their instructional practices. Eight teachers provided feedback. Initial background information on training, professional development, and students' access to the game was captured. Teacher perceptions are presented in **Table 3**.

The majority of teachers indicated that they received adequate training from the game administrators and had adequate technology skills to assist students in playing the game. On the other hand, two teachers revealed that they were unable to access technical support to resolve computer-related issues in a timely manner.

Relative to instruction, the majority of teachers sought professional development to increase their understanding of concepts covered in the game (87.5 percent) and 75.0 percent agreed to adjusting their instructional practices based on students' inquiry and feedback. The highest percentage of teachers expressed strong agreement that the science game exposed their students to information that required the use of critical thinking skills (50 percent). All respondents noted agreement with the statement that students' interest and motivation to do well in science increased following participation in the game. The most disagreement among teachers concerned changing their instructional practices since participating in the game was assigning more team projects and assigning more cooperative group tasks (28.6 percent).

Discussion

Chevron's partnership and financial support of the NDE game has resulted in the game's expansion from 2010 to 2013. The game was designed to create a learning environment that allows students to work together to solve problems that are aligned to their learning levels and to science instructional content.

Major objectives of the program are to increase students' interest and attitudes about science as well as increase their knowledge of science energy concepts. Following the first year of the program, survey results showed that students became more involved in science-related activities during and outside of school. There was also evidence that students increased their aspirations to pursue science careers and careers involving energy as adults. Outcomes noted in the second year revealed a large proportion of students indicated significant positive change in the extent that they participated in science competitions, talked to others about science, and read about science outside of school after participating in the game. Students also expressed the impact of the game on their interest in pursuing careers in science. At the same time, there was a significant decrease in the overall rating on items

that measured students' attitude about science. However, positive changes in attitude were noted in areas including that they liked to study science and had interest in learning more science from pre- to post survey.

The game's impact on students and teachers was also noted in qualitative responses provided by teachers. Specifically, teachers observed an increase in students' interest and motivation to do well in science after participating in the game. The majority of teachers modified their instructional practices to incorporate more team and web-based instructional projects. The game also served as motivation for teachers to seek additional professional development to increase their understanding of science energy concepts. Considering all of these factors, the research provides promising evidence for using computer games to improve student learning in science.

There were several limitations in the study, including the lack of a comparison group and posttest data on the majority of students. Specifically, the number of students who completed both pre- and post surveys compared to the number of students who registered to play the game was substantially lower (391 out of 1191 students). The evaluation relied on teachers to encourage their students to complete the instruments, which may have contributed to missing data and data to include for post survey analysis. Moreover, it was evident that teachers from all middle and high schools in the district were not represented in the data, thus students in all of the targeted schools did not participate. Future studies should consider having students and teachers sign written agreement to inform them about evaluation expectations and indicate their commitment to the evaluation. Although incentives were offered, these incentives should be more closely tied to study completion. In addition, efforts to recruit more teachers in all targeted schools should be strengthened to ensure a more representative study sample.

With Chevron's support, recommendations are to continue game development in similar student populations, and at other grade levels and content, to identify strategies that promote academic success for students who struggle learning science concepts. In addition, further enhancements of the game may help students learn difficult concepts and theories. Monitoring students' perceptions will support the long-term impact of the NDE game experience and the sustainability of interest and attitudes about science over time.

References

Games Research. (2011) web. science.mq.edu.au /~atychsen/ html2/ Gameresearch.htm.

Holmes, V. (2011). Research Educational Program Report. Evaluation Brief. New Century Energy Program: The Use of Games to Influence Attitudes, Interests, and Student Achievement in Science, Vol. 5, Issue 2.

Honey, M. and Hilton, M. (2010). Committee on Science Learning: Computer Games, Simulations, and Education; National Research Council Learning Science Through Computer Games and Simulations ISBN: 978-0-309-18523-3. Retrieved from http://blogs.edweek.org/edweek/DigitalEducation/2010/12/more_research_needed_on_scienc.html. http. www.nap.edu

Mundie, C, Microsoft Research, NYU and Consortium of University Partners Create First Scientific-Based Game Research Alliance to Transform Learning. Retrieved from http://www.microsoft.com/presspass/press/2008/oct08/10-07MSRNYUPR.mspx.

National Science Foundation. (n.d) Economic and Social Significance of Information Technologies: IT, Education, and Knowledge Creation. Retrieved from http://www.nsf.gov/statistics/seind98/access/c8/c8s3.htm.

National Science Foundation (2008). A Teacher for Every Learner. http://www.nsf.gov/news/overviews/computer/comp_q04.jsp

New Digital Energy (2012) Correspondence.

Texas Education Agency. (2011-2012). PEIMS Edit + Reports Data Rev

For additional information contact the HISD Department of Research and Accountability at 713-556-6700 or e-mail Research@Houstonisd.org.