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Iconic Representation in STEM Virtual Learning Environments

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Abstract

The use of imagery and iconic representation of scientific concepts is a key component in improving Critical Thinking (CT) skills while maintaining optimal Cognitive Load (CL) within higher education STEM learners. Laboratory experiences are a vital component within science education, while rote traditional lab experiments are currently not addressing inquiry nor linking with educational technologies [15]. Instructional approaches based on active discovery and problem-based learning using digital games is becoming more commonplace in today's educational forum. Opportunities to alternatively assess learning and evaluate comprehension in a digital learning environment are supportive from both a theoretical perspective [11] and an empirical research perspective [7]. Using educational games for assessment not only measures previously outlines learning objectives and goals, but allows learners to measure their cognitive load abilities in these scenarios.

Existing research regarding science learning using visualizations for information design processes such as underscoring vital information through cueing [2] and color coding [5], have focused on presenting a dynamic association between the integration of multiple representations with one another. Current research on the interaction design features of dynamic visualizations focuses on learner control and manipulation of content for best practices in the facilitation of learning [3] [4]. Iconographic representations aid learners in comprehension as a form of intervention in learners who have a lower level of prior knowledge, while this method of assistance in higher levels of prior knowledge learners would impede further learning. Interaction design features must account for expertise reversal effect in the cognitive load schema targeting long-term memory [5] [7]. By mitigating for this effect while constructing intervention processes, researcher and educators can reduce the impact on working memory through the use of carefully integrating iconic representations into learning of complex problem-solving techniques.

The research performed was a causal-comparative quantitative study with 150 learners enrolled at a two-year community college, to determine the effects of virtual laboratory experiments on CT skills and CL. Data collection involved a quantitative analysis of pre/post-laboratory experiment surveys that included a comparison using the Revised Two-Factor Study Process survey, Motivated Strategies for Learning Questionnaire, and the Scientific Attitude Inventory survey, using a Repeated Measures ANOVA test for treatment or non-treatment [14]. By studying the manner in which learners comprehend information and reducing their cognitive load while conducting scientific experiments in Virtual Learning Environments (VLEs), we are provided with the information required to structure pedagogical changes and appropriate technology resources in applicable teaching modalities [15].

1.Introduction

Dynamic visualization, such as animations, entail intricate processes, has been found to be beneficial in teh composition of laboratory schemata. Educational technology in addition to Instructional Systems Designs (ISD), have often presumed that iconic representations are adventageous when emplyiong kinetic rather than statice graphics [3]. Instructional approaches based on active discovery and problem-based learning using digital games is becoming more commonplace in today's educational forum. Opportunities to alternatively assess learning and evaluate comprehension in a digital learning environment are supportive from both a theoretical [11] perspective and an empirical research perspective [7] Using educational games for assessment not only measures previously outlines learning objectives and goals, but allows learners to measure their cognitive load abilities in these scenarios. The purpose of this article is to review the current literature pertaining to educational game play within current curricula and the possible usages as an assessment tool within higher education.

"Computer game technology is poised to make a significant impact on the way our youngsters will learn. Our youngsters are 'Digital Natives', immersed in digital technologies, especially computer games. They expect to utilize these technologies in learning contexts. This expectation, and our response as educators, may change classroom practice and inform curriculum developments" (p. 24) [7]. Multidisciplinary research has shown that the design, development, and implementation of computer games within the educational realm. Digital natives [7] were raised in digital environments that utilize computer games in everyday occurrences. According to the Partnership for 21st Century Skills [13], levels of creativity and innovation skill set, in addition to communication abilities and technological literacy, were considered highly advantageous for tomorrow's learners. These skill sets could lead educators to incorporating game modification as part of future learning modalities [1, 2].

The purpose of this quantitative quasi-experimental study was to determine how the use of iconic-representation in virtual learning environments, and how they are requisite of manipulating more than one parameter which can alter the complexity of a learning scenario. This yields an increase in cognitive load, specifically for inexperienced learners. The data revealed that the inclusion of iconic representation can enhance the learning process in inexperienced learners. This was accomplished by measuring Critical Thinking (CT) skills, and Cognitive Load (CL) among learner participants at a two-year community college. The Force Table experiment describes the relationship between vectors and vector analysis. The version of the simulation presented in Fig. 1 uses icons to represent the vector components, which are essential to the learning process. While Fig. 2 depicts an animiation without iconic representation. A distinction exists between iconic and symbolic representation of phenomena that is based upon taxonomic representations that amplify in their intricacy and generalization. Homer and Plass [3] noted that a progressive development between learning contextual usage of terms based upon pictorial representation and abstract meanings used in vernacular culture. These icons were integrated into the simulation to assist beginner physics learners ascertain the visual representation of the simulation by offsetting their lack of domain-specific topical antecedent comprehension. Past research has demonstrated that the inclusion of said icons in scientific simulations can aid in the reduction of cognitive load, specifically for those learners with low prior knowledge of topical material [3].

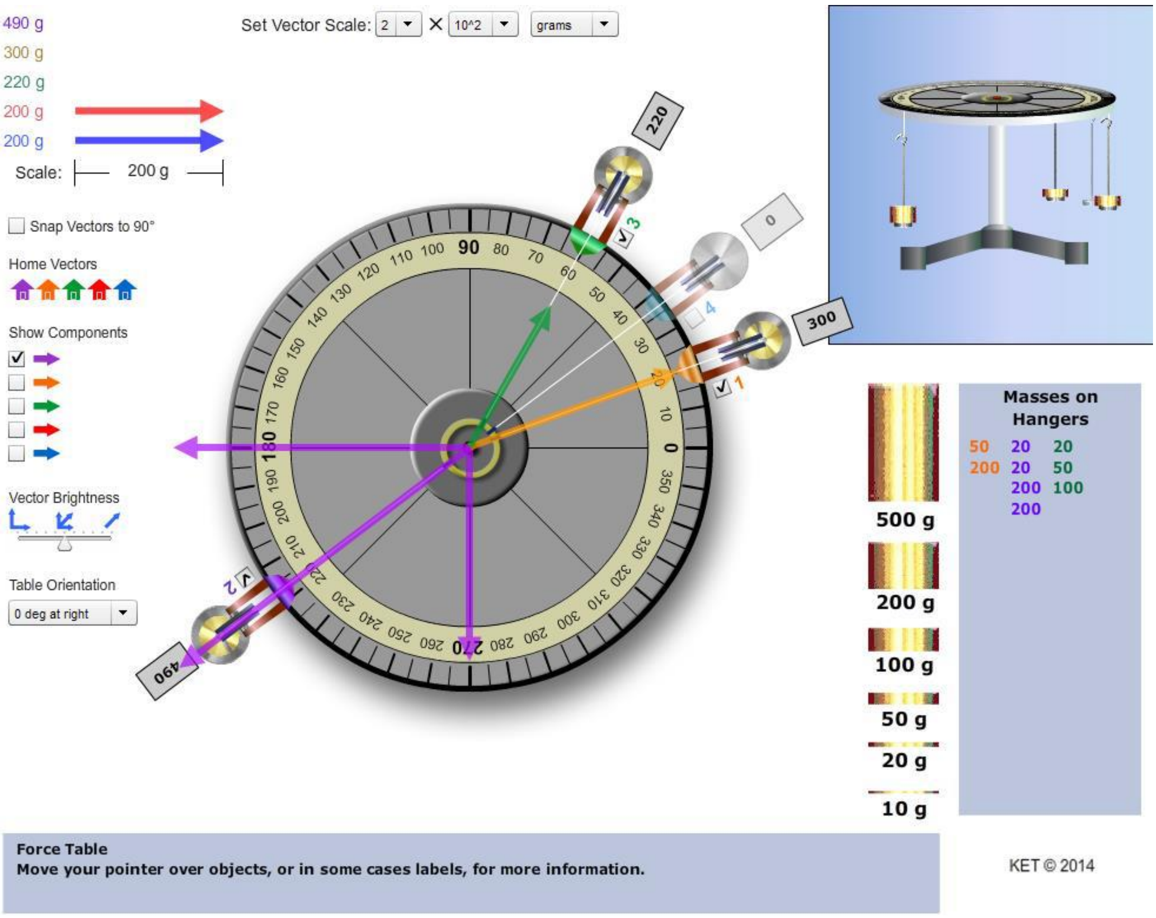

Fig. 1. Force Table narrated visualization with iconic representation

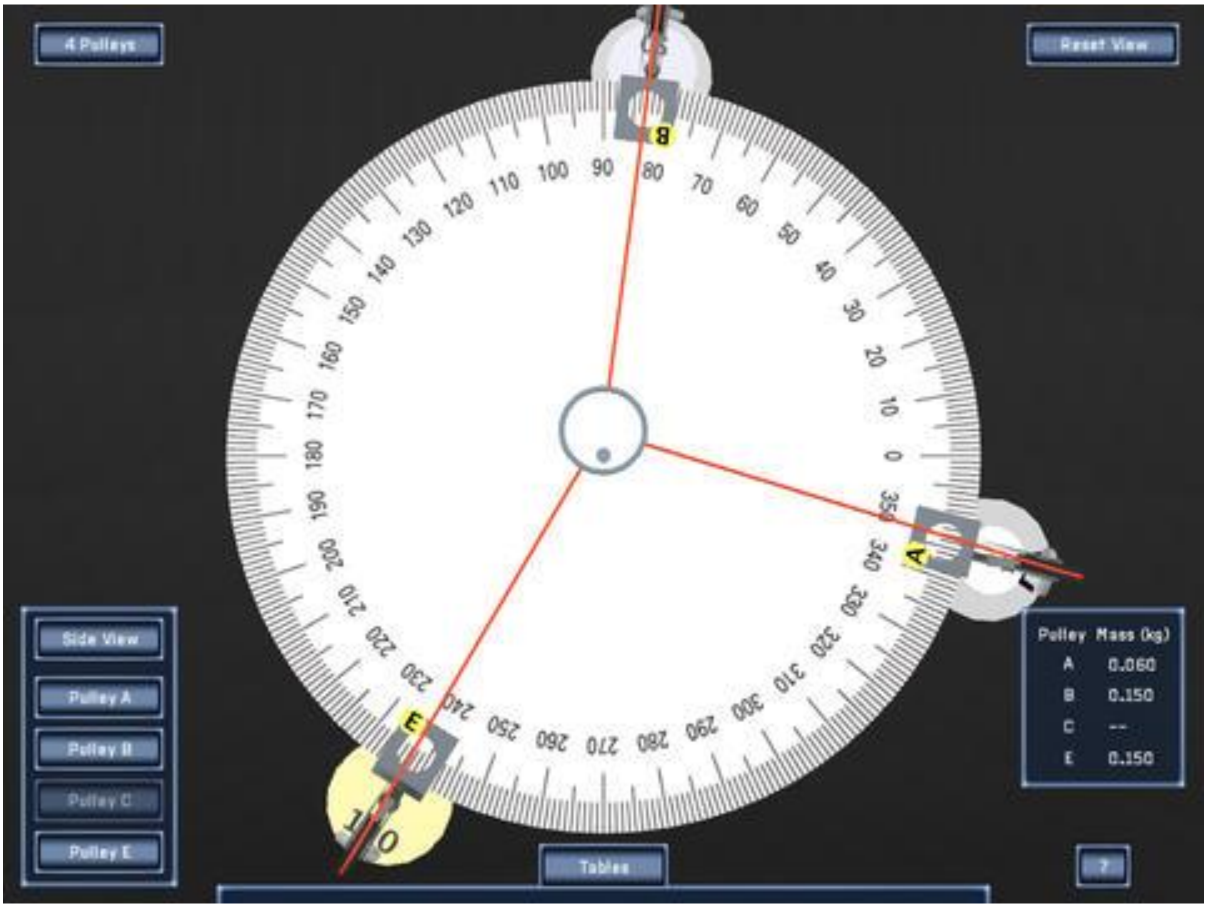

Fig. 2. Force Table narrated visualization with-out iconic representation

2. Results

The results of the presented study are based on data collected during an academic year. Each learner provided informed consent to the collection of this data. All data are anonymized as to avoid any personally identifiable information.

Critical Thinking (CT) Skills were assessed as to the extent in which they differed for learnesr exposed to iconic representation during visualization of the *Force Table* than those with no treatment. Results of the statistical analysis of the repeated measures indicated that the use of icons had some effect on the learning process. The results indicated that the iconic representation in the treatment group does increase the use of CT Skills. The use of CT Skills with icons consisted of two main subscales, deep learning and surface learning. The results showed that learners in the treatment (icon experiment modalities) group had higher levels of CT Skill usage and implementation than learners in the non-treatment (non-icon experiment modalities) group. Fig. 3 represents the results in academic grades for those learners receiving treatment. There was no statistical significant changes for those learners without treatment.

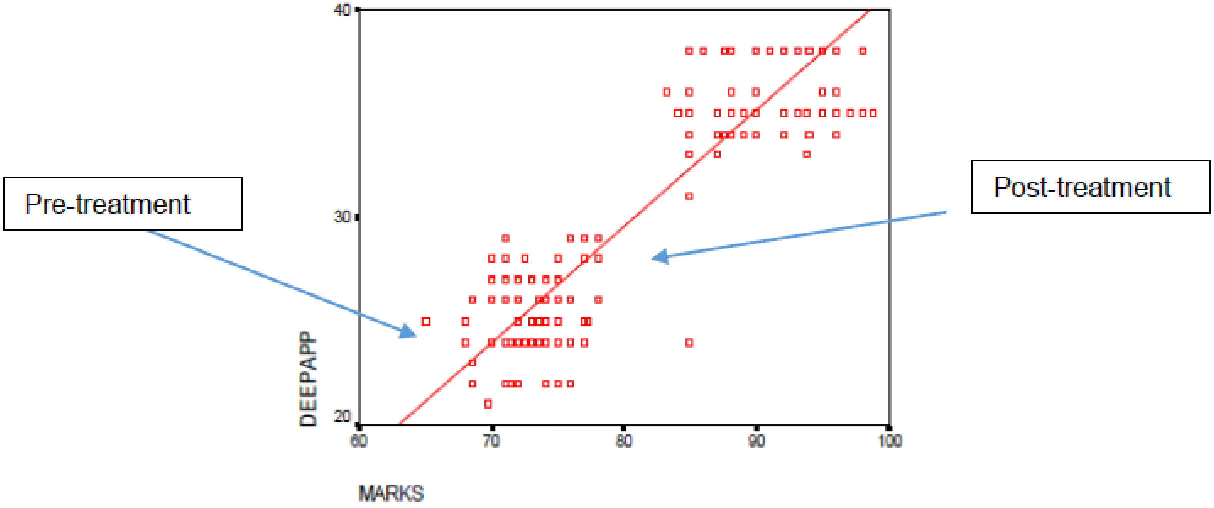

Fig. 3 Positive Comparision of deep level learning of Critical Thinking Skills and Grades for Iconic-Representation

The findings from this research are that those learners in the treatment group thought more critically and analytically than learners in the non-treatment group, is consistent with past research on the usage of iconic represenation in laboratory experiments within the science disciplines [3, 4, 9]. There are three components integral in science education within the domain of higher-order cognitive skills development include: problem-solving, CT, and laboratory practice. The results are significant in that they indicate the use of CT Skills in a deep and surface learning capacity. The research findings denoted that learners are using more in-depth methods for scientific analysis through the use of CT. The inclusion of critical thinking, within experimentation, is evident that the progression of synthesis and evaluation of learner material is ongoing [2].
Cognitive Load (CL) capacity was assessed as to the extent in which they differed between the use of iconic representation in laboratory experiments when compared pre- and post-laboratory experiments. Results of the statistical analysis of the repeated measures indicated that the use of the icons in the treatment group does not statistically show great significance in the CL. The effective use of Cognitive Load with icons is marginally reduced and therefore, somewhat significant, as the within groups showed more efficient use of working memory than that of the between group results. The results showed that learners in the treatment group had moderately higher levels of CL usage and implementation than learners in the non-treatment group. The findings from this research are that those learners in the treatment group used similar levels cognitive load capabilities as did learners in the non-treatment group, is consistent with past research on the usage of iconic reprsentation in laboratory experiments within the science disciplines [4, 5, 19, 20].

3.Summary and conclusion

The impact of iconic representation in science laboratory experiments, on learning developing, Critical Thinking (CT) skills and Cognitive Load (CL) capabilities, is studied. A pre/post survey methodology is introduced, as to distinguish learning events during experimentation. Statistical results are presented that show Critical Thinking Skills can be achieved as well as increased Cognitive Load ability in iconic-based laboratory learning environments. With the incorporation of these learning environments into laboratory courses, learners may increase their knowledge base within defined course content areas more expressly directed at the science disciplines. The research study showed that, when utilized properly, simulation experiments can facilitate an environment for learning that develops and fosters Critical Thinking and Cognitive Load gains. These variables will help to maintain or exceed Cognitive Load abilities; explicitly aimed at the scientific disciplines, scientific technology, and overall scientific awareness. Instructional and educational design of a course aids in the determination of whether a learner utilizes deep or surface learning through Critical Thinking and Cognitive Load abilities [14, 15]. This study offered a discrete perspective for science educators with interests in simulation experiments and for educational technologists interested in creating these learning environments. The requirements for learners in laboratory courses is to master scientific concepts and engage in meaningful knowledge through learning approaches that can be used for a multitude of educational and career pathways.

References

[1] Bartholow, B. D., Sestir, M. A., & Davis, E. B. (2005). Correlates and consequences of exposure to video game violence: hostile personality, empathy, and aggressive behavior. *Personality and Social Psychology Bulletin*, *31*(11), 1573–1586. doi:10.1177/0146167205277205

[2] Gee, J. (2008). Game-like learning: An example of situated learning and implications for opportunity to learn. In P. A. Moss, D. C. Pullin, J. P. Gee, E. H. Haertel, & L. J. Young (Eds.), *Assessment, equity, and opportunity to learn* (pp. 200–221). New York, NY: Cambridge University Press.

[3] Homer, B., & Plass, J. (2010). Expertise reversal for iconic representations in science simulations. *Instructional Science, 38,* 259–276.

[4] Kalyuga, S., & Plass, J. (2007). Managing Cognitive Load in Instructional Simulations. In M. Nunes & M. McPherson (Eds.), *Proceedings of the IADIS International Conference e-Learning 2007*, 27-34. Lisbon, Portugal.

[5] Keller, T., Gerjets, P.; Scheiter, K., & Garsoffky, B. (2006). Information visualizations for knowledge acquisition: The impact of dimensionality and color coding. *Computers in Human Behavior*, 22(1), 43-65.

[6] KET Virtual Physics Labs. http://virtuallabs.ket.org/physics/

[7] O'Brien, D., Lawless, K., & Schrader, P. (2010). A Taxonomy of Educational Games. In Y. Baek (Ed.), *Gaming for Classroom-Based Learning: Digital Role-Playing as a Motivator of Study*, 1-23, Hershey, PA: IGI Global.

[8] Partnership for 21st Century Skills. (2006). *Results that matter: 21st century skills and high school reform*. Tucson, AZ: Partnership for 21st Century Skills.

[9] Plass, J.L., Homer, B.D., Milne, C., Jordan, T., Kalyuga, S., Kim, M., & Lee, H.J. (2009). *Design Factors for Effective Science Simulations: Representation of Information*. International Journal of Gaming and Computer-Mediated Simulations, 1(1), 16-35.

[10] Polhyedron Physics Labs. http://www.polyhedronlearning.com/see_vpl.html

[11] Prensky, M. (2001). Digital natives, digital immigrants. *Horizon*, *9*(5). http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf. Retrieved September 26, 2014.

[12] Price, C., & Moore, J. (2010). The Design and Development of Educational Immersive Environments: From Theory to Classroom Deployment in *Gaming for Classroom-Based Learning*. Ed Young Baek. ICI Global. DOI: 10.4018/978-1-61520-713-8

[13] Pyatt, K., & Sims, R. (2011). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance, and access. *Journal of Science Educational Technology*. doi:01.1007/s10956-011-929-6.

[14] Simon, N. (2014). Simulated and Virtual Science Laboratory Experiments: Improving Critical Thinking and Higher-Order Learning Skills. In M. Searson & M. Ochoa (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2014*, 453-459. Chesapeake, VA: AACE.

[15] Simon, N. (2015). Improving Higher-Order Learning and Critical Thinking Skills using Virtual and Simulated Science Laboratory Experiments. In K. Elleithy & T. Sobh (Eds.), *New Trends in Networking, Computing, E-learning, Systems Sciences, and Engineering*, 312, 187-192. doi:10.1007/978-3-319-06764-3_24