Virtual Solar Energy Center Case Studies

Kenneth A. Ritter III, Christoph W. Borst, and Terrence L. Chambers

***Abstract*— This paper presents a study on the use of virtual reality (VR) technologies for teaching concentrating solar power (CSP) to high school and university students. The main goal is to develop an interactive and immersive VR application to explain the main components and processes used in a CSP plant. The secondary goal is to test the effectiveness of this application by performing case studies. The studies are assessed with pre-test, post-test, and questionnaires. In the initial desktop version, there is a substantial improvement on the post-tests that demonstrates that this type of application can be used as an educational tool. The immersive application achieved testing results in the final study that were similar to other methods assessed and scored 88% positive results on the experience questionnaire.**

***Index Terms*—engineering education, immersive education, virtual reality, solar power**

I. Introduction

USING computer aided design (CAD) software, a scale model of an actual alternative energy research facility in Louisiana was imported into a game engine to create a Virtual Solar Energy Center (VSEC) educational application. Interactive educational activities were placed throughout the virtual environment, and the student was required to complete each activity to virtually produce solar power. The purpose of this application was to teach students about the major components of a CSP plant and how they worked. The application utilizes a VR headset for immersive visuals and head tracking, hand controllers for pointing-type tracked interactions and other inputs, and a 3D camera to capture a teacher or guide. With Microsoft Kinect, a live, 3D image of the solar energy expert was able to remotely interact with high school students, answering questions and providing guidance. The final version has been built with networking capabilities, allowing multiple students to interact with each other within the VSEC.

This type of application can give future engineers the convenience of experiencing complex processes visually by viewing animations in an immersive environment. Previously, the authors summarized the VSEC, describing VR interaction techniques and ongoing work regarding depth camera and networking aspects [1]. Following this, the authors provided a much more complete description of the VSEC study and initial results from university students and a small STEM high school class [2]. Since then, demonstrations were performed at conferences and university events to verify the capabilities of the application and gain feedback on the user experience. Along with the demonstrations, there were four comparative analysis studies performed with the application from late 2015 to early 2016. These studies used differing techniques for presenting the same information to determine the effectiveness of the various training methods. Feedback questionnaires were administered to gather user experience information to further validate the results. The results were used to continually revise the application and assessment techniques for the next study. This paper presents these results.

II. Literature Review

Immersive applications increase student motivation and engagement which in turn results in effective instruction [3]–[5]. Exploration, interaction, and collaboration provide strong educational opportunities in these immersive learning environments [6]. The first-person immersive view provides students with a better understanding of the size and the spatial arrangements of energy device components. And immersion in a virtual environment has been shown to help students better understand dynamic three-dimensional processes [7].

Several previous studies were evaluated to determine how to assess the effectiveness of a VR application to comprehend complex engineering devices. The use of pre- and post-test analysis as well as feedback questionnaires have been widely used as methods of assessment for VR, game-based, and other alternative teaching methods [8]–[14]. One study about aviation safety had participants divided into an immersive game-based group and a paper-based group [9]. Pre- and post-tests were used for evaluation, and it was found that the immersive environment was more engaging and fear-arousing, resulting in superior retention. Another study compared an immersive virtual environment to a desktop version about simulated water movement and salinity in the ocean [7]. Using pre- and post-tests, it was found that immersion is only helpful when the educational content is complex, three-dimensional, and dynamic. For software engineering training, one study used a 3D game-based environment and compared it to face-to-face

K. Ritter is a research scientist in the College of Engineering, University of Louisiana at Lafayette, Lafayette (e-mail: kar4499@louisiana.edu)

C. Borst is an associate professor at the Center for Advanced Computer Studies, University of Louisiana at Lafayette, Lafayette (e-mail: cxb9999@louisiana.edu)

T. Chambers is an associate professor in the College of Engineering, University of Louisiana at Lafayette, Lafayette (e-mail: tlc3715@louisiana.edu)

teaching [14]. Using pre- and post-tests with questionnaires, it was found that higher learning achievement and motivation were gained from the 3D game-based method. Immersive training has been used for mechanical assembly where participants assembled an actual rocket motor after learning how to do it virtually [15]. Although this was not a comparative study, participants were able to assemble the physical motor with over 95% accuracy after doing so virtually. A current study suggest that students will learn as much or even more in a virtual reality environment of a computerized numerical control (CNC) milling machine [16]. Their CNC milling machine is currently being developed as an educational tool to be used for online and distance learning.

III. START Lab

The Solar Technology Applied Research and Testing (START) Laboratory, shown in Figure 1, is a pilot-scale CSP plant that is the first university-owned facility of its type and size in the United States [17]–[20]. It supports research on next-generation solar devices and provides outreach activities to educate K-12 students about solar energy and other forms of renewable energy. Physical tours provide limited opportunities for educational experiences because it is difficult for many students to travel to the START Lab due to geographical or scheduling constraints. For broader delivery of educational experiences, the virtual solar energy center (VSEC), shown in Figure 1, was developed. The initial creation of a scale 3D model of the real energy facility for guided virtual tours to groups of students visiting projection display rooms is described in [21].

Fig. 1. Bird's-eye view of the real (left) and virtual (right) facility.

IV. Method

About fifty high school and university participants were involved in each of the case studies. The majority of participants in these studies were engineering students who are primarily male as shown in Table 1. Volunteer students were requested from teachers who supported the study in local high schools and from professors who were involved at the University. Institutional Review Board (IRB) documents were approved prior to every study. For high school students parent signatures were required before any student could participate. The immersive application used two systems of control: a non-immersive desktop version of the same application and a PowerPoint presentation video. The presentation video is used as the traditional teaching control method. The immersive application and desktop application had many similarities but differed in display and control. All immersive application versions used a VR headset (Oculus Rift DK2) for display and tracked controllers (Razer Hydra) to interact with the environment. For the desktop application, a laptop or desktop monitor was used for display and a mouse and keyboard were used for controls. The presentation video was narrated and contained the same audio content and 2D pictures in the applications. Once the video was started no controls were needed. All testing methods used over-ear stereo headsets with microphones. A summary of the four studies and participants involved is shown in Table I.

TABLE I
THE FOUR COMPARATIVE ANALYSIS STUDIES PERFORMED WITH ASSOCIATED PARTICIPANTS

Study	Organization	Application Type	Male	Female	Total	Ages
1	David Thibodeaux STEM Magnet Academy	Desktop	6	2	8	17-18
	University of Louisiana at Lafayette	Desktop	36	5	41	19 and up
2	David Thibodeaux STEM Magnet Academy	Presentation Video	29	7	50	14-18
		Immersive	9	5		
3	Comeaux High School	Desktop	18	6	51	15-18
		Immersive	14	13		
4	University of Louisiana at Lafayette	Presentation Video	19	2	46	19 and up
		Immersive	22	3		

The initial study, Study 1, used two different participant groups, both of whom experienced the same application. The first group of participants tested comprised high school students at DTSMA and the next group were university undergraduates and graduates at the University of Louisiana at Lafayette (UL Lafayette). High school participants were tested in a small room at DTSMA and university participants were tested at the Virtual Reality Lab in Rougeou Hall at UL Lafayette. The next three studies each compared two application types within a single organization.

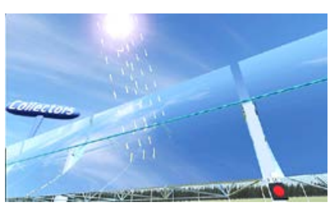
Fig. 2. DTSMA students testing the immersive application, left and the presentation video, right.

Study 2 at DTSMA, shown in Figure 2, had one group of students watch a presentation video while the other completed the immersive application. The presentation video used 2D pictures of the same content presented in the immersive environment as well as accompanying explanatory audio. The presentation video represents one conventional method of teaching or training. The immersive environment was compared to the 2D video method to test the effectiveness of the application for learning and to assess the participant experience.

Study 3 was performed at Comeaux High School (CHS) and had two groups of students using immersive and desktop versions of the same application. In the immersive version, a networking feasibility test was conducted on some of the participants to investigate if a teacher or guide at UL Lafayette could join students in the application to aid in explanations and to answer questions. The teacher avatar could point to objects to help support verbal descriptions. Once the students would start the application, the teacher would appear in the tower area, shown in Figure 3(a), to give all students initial instructions. The teacher would then appear at the condenser station, shown in Figure 3(e), to meet with an individual student to clear up any misconceptions and answer questions. Also, in the immersive version, students were networked together, allowing them to see and hear each other in the virtual environment.

Study 4 was conducted using university students at UL Lafayette. Two groups of students were tested, comparing presentation video to the immersive application. In this study, the immersive application allowed for locally networked teacher to be projected into the application, as shown in Figure 3(f), who could then serve as a guide and answer questions. As in the previous study, the teacher would initially appear in the tower to greet all participants and then meet an individual at the end to clear up any misconceptions and answer questions. However, this study differed in using a depth camera to project the teacher into the scene rather than an avatar used in the previous study. The application for this study, shown in Figure 3, consisted of a welcome area and four interaction areas.

(a) Tower Area



(b) Collector Area


(c) Boiler Area


(d) Turbine & Generator Area


(e) Condenser Area

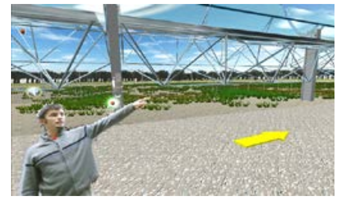

(f) Networked Teacher

Fig. 3. The five interaction areas(a-e) and networked teacher(f).

Each area had several interactable objects that mainly consisted of users clicking on icons or glowing objects that would trigger a 3D animation and accompanying audio explanation. As shown in Figure 3(a), the tower area was used for welcoming and instruction on traveling and controls for the four component interaction areas. To provide a more engaging user experience, each user input had an accompanying 3D animation with a complementary voiceover component. The animations included sun rays reflecting off the mirrors to show linear focus (Figure 3(b)), a pop-out translucent boiler with moving fluids to show cross-flow heat transfer and vaporization of the refrigerant (Figure 3(c)), a pop-out rotating turbine and rotor to show the thermal to mechanical energy transfer (Figure 3(d)), and an exploding condenser heat exchanger to show the surface area of parallel plates used to increase heat exchange (Figure 3(e)). The associated test questions in each study were structured to closely resemble the learning content in the application.

The applications would take users between ten and 20 minutes to complete. The learning outcomes were measured by pre-test assessments, post-test assessments, and a questionnaire that provided feedback on the application experience. Each of these would take 4 to 7 minutes a piece, bringing the total testing time to about 30 minutes per student. Upon completion, students were expected to have a basic understanding of a complex engineering power cycle, the organic Rankine cycle, used in a solar thermal power plant. The tests administered had between 12 and 14 questions worth one point each for pre- and post-tests. All questions were multiple-choice and mainly pertained to the functions of the major components of a CSP plant. Questions such as, "Where is thermal energy absorbed and transferred?" and "What vaporizes in the boiler to create a high-pressure vapor?" were used. The post-tests were administered immediately after students finished the application or watched the video. Following the post-test, a user-experience questionnaire was administered to students who completed the application. Students who only watched the presentation video were not given the questionnaire. The questionnaire consisted of ten to 27 questions to judge the users' experience within the application and to gather feedback for improvement. The first set of questions followed a five-point Likert scale where students were asked to rank their experience from one to five ranging from strongly agree (5) to strongly disagree (1) with the statement given. The uses' experience questions were developed to gauge the comfortability of the VR experience, the controls, the content, the topic, the engagement of the user, motivation level, distractions, attentiveness, concept difficulty, overall satisfaction, and enjoyment of the experience. The next set of questions was regarding the user experience level with video games and virtual reality. Finally, three open-ended questions were asked for feedback of positive and negative aspects of the game and suggestions for improvement.

V. Results

A. Testing Results

The results of the four studies are presented in the following section. The participants were given a pre-test assessment and then a post-test following the completion of their assigned application. As shown in Table 2, the average percent gain <%gain> is highest in the desktop application. However, this gain is highly dependent on the pretest score which varies amongst groups tested. To remain consistent across each participant group and application type, the average effectiveness of the application in promoting conceptual understanding was taken to be the average normalized gain [12]. The average normalized gain <g> is defined as the ratio of the actual average gain (% post - % pre) to the maximum possible average gain (100% - % pre).

TABLE II
THE PRE- AND POST-TEST RESULTS FOR THE FOUR STUDIES

Study	Participants	<%pre>	Application Type	<%post>	<%gain>	<g>
1	David Thibodeaux STEM Magnet Academy	39	Desktop	61	19	0.33
	University of Louisiana at Lafayette	52	Desktop	74	22	0.46
2	David Thibodeaux STEM Magnet Academy	36	Presentation Video	52	16	0.25
		41	Immersive	47	7	0.11
3	Comeaux High School	52	Desktop	72	21	0.42
		53	Immersive	60	6	0.13
4	University of Louisiana at Lafayette	60	Presentation Video	77	17	0.43
		66	Immersive	81	14	0.43

In Study 3 a networked teacher avatar did successfully enter the scene and meet with five students at the beginning and end of the application. In Study 4 the projected networked teacher, shown in Figure 3(f), was able to successfully enter the scene to explain instructions for the initial start of the application for all participants and to quiz and answer questions at the end of the application for some participants.

The normalized gain from the four studies using the three different application types are graphed with error bars in Figure 4. The average high school (HS) and university (UL) normalized gains are shown in the orange boxes with university students having considerable higher average normalized gain over all tests than the high school students.

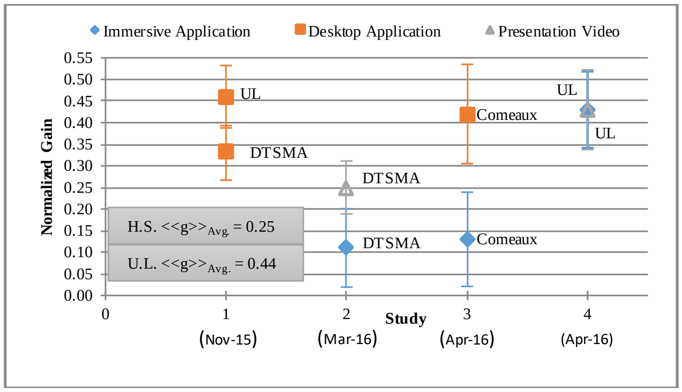


Fig. 4. Results with error bars from four studies organized by application type with average high school (HS) and university (UL) normalized gains.

Due to the highly variable test performance, there are large distributions of the pre- and post-test scores as shown with the error bars of the normalized gain in Figure 4. If the characteristics of the participants vary with a multiplicity of understandings, abilities, skills, and attitudes, and this affects test performance, then it would be expected that this randomness would follow a near Gaussian distribution for a high number of participants [22]. These statistical fluctuations in the gain are not the result of experimental error in most cases but are due to the highly variable characteristics of the participants tested.

As shown in Figure 4, the desktop application only varied slightly between the first and third studies while the immersive application gain increased significantly. The immersive application was continually revised following questionnaire results, and testing results of the previous study. The improvements led to the elimination of the gap between immersive and non-immersive in the last study. The improvements included better graphics, the addition of 3D models and animations, increased user interactions, improved voice over content and audio quality, more precise movement and control, and isolated testing environments.

B. Questionnaire Results

All students who completed the application were given a questionnaire to complete as stated in the method section. A condensed version of some of the results for the four study groups are shown in Table 3.

TABLE III
QUESTIONNAIRE RESULTS FOR THE FOUR STUDY GROUPS

Study	Organization	Application Type	% Positive Questionnaire	Most Common Positive Feedback	Most Common Negative Feedback	Most Common Other Comments
1	David Thibodeaux STEM Magnet Academy	Desktop	82	Informative or Educational	Movement	Positive Experience, enjoyed topic
	University of Louisiana at Lafayette	Desktop				
2	David Thibodeaux STEM Magnet Academy	Presenta-tion Video	75	Immersive, Fun, Easy to Learn	Graphics, Feel Dizzy / Nauseaus	Surroundings are distracting
		Immersive				
3	Comeaux High School	Desktop	74	Informative, Educational	Controls	Easy to Learn & Good for Students
		Immersive	81	Immersiv e, Interestin	Audio \ volume	Fun
4	University of Louisiana at Lafayette	Presenta-tion Video	88	Graphics, Immersive, Easy to learn	Blurry or can't wear glasses, No movement	Immersive is distracting
		Immersive				

The questionnaire was designed for application participants so therefore given only to subjects who completed the desktop or immersive application. "The animations are helpful in understanding the topic" was the one of the most agreed upon statements in all studies. "I would like to learn other topics this way" was the most agreed upon statement in the immersive application in Study 3 and 4.

VI. DISCUSSIONS

In Study 1, both groups of students showed a significant gain after performing the desktop application. The high school participants at DTSMA had a lower normalized gain than the UL Lafayette participants. The questionnaire had highly positive comments at 82%, and the most popular comments included being informative or educational, interesting subject, positive experience, and easy to learn. This would suggest that this type of application was an enjoyable and informative experience for users and can be used for educational purposes. The next step of comparing a traditional teaching method to this application was the subject of the subsequent studies.

For Study 2, both groups' average normalized gain fell in the low gain region with presentation video group having a 14% higher average normalized gain than the immersive group. Mostly positive questionnaire results, 73%, were given, however many comments were negative. Over 50% of subjects in the immersive group commented on the poor graphics or something related, such as blurred vision, dizziness or nauseous feelings. The framerate was below 70 FPS at some parts of the application and this resulted in a slow and skipping display. The low framerate causing lag and dropped frames is discomforting in VR and would result in some subjects quitting early. The framerate should be equal or higher than the screen's refresh rate, v-synced and unbuffered to eliminate any lag and dropped frame issues. Also, several students commented that the initial surprise of being fully immersed in the virtual environment was distracting.

In Study 3, the desktop group results were in the medium-gain region and the average normalized gain was 29% higher than the immersive group. The immersive application was rated as a fun and positive experience with the immersive quality being the most positive factor. The desktop application was rated as easy to learn and informative but received less positive feedback from the experience questionnaire. Although the applications were identical in the visualizations and audio content, the immersive version was networked, causing both a lowered volume and distractions from other subjects' avatars. As immersion is a relatively new medium for training, the initial experience was found to be distracting for participants to focus on the learning content.

For Study 4, the averaged normalized gain was the same for each of the control groups, with the immersive results achieving medium gain for the first time. The results of the immersive questionnaire were highly positive at 88%. The graphics or visuals were the most common positive feedback for the final immersive study, whereas they were the most common negative feedback in Study 2. There were many negative comments about glasses not being allowed to be worn in the VR headset and blurry vision. If students have poor eyesight, their prescription glasses should be worn inside the headsets. The next most common negative comment was regarding movement restrictions. This version had participants teleport directly to each area instead of game-like controller-based walking, which helped to mitigate motion sickness problems.

VII. CONCLUSIONS

As shown in the results of Study 1, after playing the 10- to 15-minute non-immersive application, students showed considerable improvement on the post-test. The vast majority of comments were positive, and nearly 80% of subjects commented that the application was either easy to learn, informative, or educational. When finished, many students expressed that they enjoyed the experience and would like to play more. Therefore, it can be concluded that this type of application is promising as an educational tool that students appreciate. As may be expected, the initial version of the immersive application performed poorly, but after each revision, better results were achieved. Along with better results the percentage of positive responses from the experience questionnaire increased with each study, reaching 88% for the final tested version. With the addition of teleportation, in lieu of game-like controller-based walking, no dizziness or nausea was reported.

The immersive application for the fourth study achieved similar effectiveness as the other methods assessed. As computing technologies increase, virtual training environments will more closely resemble photorealism [3], [16]. Following this trend from these studies, the effectiveness of VR-based training could pass traditional methods for specific applications.

VIII. Recommendations for future educational VR applications:

- With the animations being the highest rated overall with studies in helping to understand the topic, it is suggested that animating products and processes facilitate explaining difficult concepts.
- Use teleportation instead of controller-based walking to mitigate perceived motion sickness effects.
- The testing environment should be a quiet room with minimal subjects and is free from outside distraction.
- An initial training program should be performed by future participants to acquaint users with the immersive environment before performing the study.
- If networking is used, the students should not see each other's avatar for the immersive to be useful.
- Long-term retention should be assessed by testing participants a week or more following the application. VR has been shown to have an advantage over traditional methods in long-term retention [9].
- Assessment techniques should be deployed both to measure the improvement in learning outcomes using VR techniques against traditional teaching methods and to compare the relative effectiveness of using one VR technique rather than another.

IX. Acknowledgments

This material is partly based upon work supported by the National Science Foundation under Grant Number 1451833 and is partially supported by the Louisiana Board of Regents through the Board of Regents Support Fund, (contract LEQSF(2015-16)-ENH-TR-30). This work is also partially supported by Cleco Power, LLC. Several graduate and undergraduate students aided in this work including Lance Lasseigne, Jonathon McRae, Matthew Prilliman, and Sam Ekong. Nicolette Darjean and the teachers at DTSMA helped inform students and organize the high school study.

X. References

[1] C. W. Borst, K. A. Ritter III, and T. L. Chambers, "Virtual Energy Center for Teaching Alternative Energy Technologies," in *IEEE VR 2016 Conference*, 2016, pp. 157–158.

[2] K. A. Ritter III, T. L. Chambers, and C. W. Borst, "Work in Progress : Networked Virtual Reality Environment for Teaching Concentrating Solar Power Technology," in *2016 ASEE Annual Conference & Exposition*, 2016, pp. 1–18.

[3] A. G. Abulrub, A. N. Attridge, and M. A. Williams, "Virtual Reality in Engineering Education: The Future of Creative Learning," in *IEEE Global Engineering Education Conference (EDUCON)*, 2011, pp. 751–757.

[4] T. J. Bastieans and F. Hagen, "New Landscapes and New Eyes : The Role of Virtual World Design for Supply Chain Education," vol. 6, no. 1, pp. 37–49, 2014.

[5] J. Psotka, "Educational Games and Virtual Reality as Disruptive Technologies.," *Educ. Technol. Soc.*, vol. 16, no. 2, pp. 69–80, 2013.

[6] H. Tüzün, M. Yilmaz-Soylu, T. Karakuş, Y. Inal, and G. Kizilkaya, "The Effects of Computer Games on Primary School Students' Achievement and Motivation in Geography Learning," *Comput. Educ.*, vol. 52, no. 1, pp. 68–77, 2009.

[7] W. Winn, M. Windschitl, R. Fruland, and Y. Lee, "When Does Immersion in a Virtual Environment Help Students Construct Understanding ?," *ISLS Int. Soc. Learn. Sci.*, no. 206, pp. 497–503, 2002.

[8] L. Bao, "Theoretical comparisons of average normalized gain calculations," *Am. J. Phys.*, vol. 74, no. 10, p. 917, 2006.

[9] L. Chittaro and F. Buttussi, "Assessing Knowledge Retention of an Immersive Serious Game vs. a Traditional Education Method in Aviation Safety," *IEEE Trans. Vis. Comput. Graph.*, vol. 21, no. 4, pp. 529–538, 2015.

[10] M. Ebner and A. Holzinger, "Successful implementation of user-centered game based learning in higher education: An example from civil engineering," *Comput. Educ.*, vol. 49, no. 3, pp. 873–890, 2007.

[11] J. Holmes, "Designing agents to support learning by explaining," *Comput. Educ.*, vol. 48, no. 4, pp. 523–547, 2007.

[12] R. R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.*, vol. 66, no. 1, pp. 64–74, 1998.

[13] M. Shah and A. Foster, "Undertaking an Ecological Approach to Advance Game-Based Learning : A Case Study," *Educ. Technol. Soc.*, vol. 17, no. 1, pp. 29–41, 2014.

[14] C. Su and C.-H. Cheng, "3d Game-Based Learning System for Improving Learning," *TOJET Turkish Online J. Educ. Technol.*, vol. 12, no. 2, pp. 1–12, 2013.

[15] J. E. Brough, M. Schwartz, S. K. Gupta, D. K. Anand, R. Kavetsky, and R. Pettersen, "Towards the development of a virtual environment-based training system for mechanical assembly operations," *Virtual Real.*, vol. 11, no. 4, pp. 189–206, 2007.

[16] H. A. El-mounayri, C. Rogers, E. Fernandez, and J. C. Satterwhite, "Assessment of STEM e-Learning in an Immersive Virtual Reality (VR) Environment," in *American Society for Engineering Education*, 2016, pp. 1–12.

[17] T. L. Chambers, J. R. Raush, and G. H. Massiha, "Pilot solar thermal power plant station in southwest Louisiana," *Int. J. Appl. Power Eng.*, vol. 2, no. 1, pp. 45–52, 2013.

[18] J. R. Raush and T. L. Chambers, "Initial field testing of concentrating

solar photovoltaic (CSPV) thermal hybrid solar energy generator utilizing large aperture parabolic trough and spectrum selective mirrors," *Int. J. Sustain. Green Energy*, vol. 3, no. 6, pp. 123–131, 2014.

[19] T. L. Chambers, J. R. Raush, and B. Russo, "Installation and Operation of Parabolic Trough Organic Rankine Cycle Solar Thermal Power Plant in South Louisiana," *Energy Procedia*, vol. 49, no. 2014, pp. 1107–1116, 2014.

[20] J. R. Raush, T. L. Chambers, B. Russo, and K. Crump, "Assessment of local solar resource measurement and predictions in south Louisiana.," *Energy, Sustain. Soc.*, vol. 6, no. 1, pp. 1–12, 2016.

[21] K. A. Ritter III and T. L. Chambers, "Educational Gaming and Use for Explaining Alternative Energy Technologies," *Int. J. Innov. Educ. Res.*, vol. 2, pp. 30–42, 2014.

[22] R. R. Hake, "Relationship of Individual Student Normalized Learning Gains in Mechanics with Gender , High-School Physics , and Pretest Scores on Mathematics and Spatial Visualization," *Phys. Educ. Res. Conf.*, no. August, pp. 1–14, 2002.

Kenneth Ritter is a concentrating solar power research scientist at the University of Louisiana at Lafayette. He has an MS in Solar Energy Engineering from Högskolan Dalarna in Borlänge, Sweden. Kenneth earned his Ph.D. in Systems Engineering with a mechanical concentration in August 2016 and directed the development of the Virtual Solar Energy Center (VSEC) virtual reality lab at the University of Louisiana at Lafayette. His research interests include solar power, virtual reality, and engineering education.

Terrence Chambers serves as an associate professor of Mechanical Engineering at the University of Louisiana at Lafayette. His research interests include engineering design and optimization, artificial intelligence, virtual reality, and alternative energy. He is an active member of ASEE, ASME, LES, and is a registered Professional Engineer in Louisiana.

Christoph W. Borst received a BS degree in Computer Science from the University of Texas and a PhD in Computer Science from Texas A&M University. He is an associate professor at the Center for Advanced Computer Studies at the University of Louisiana at Lafayette. His research areas include visualization, 3D interaction, and haptics. His recent work in these areas included virtual reality techniques for data exploration, telerobotics, and education.