

The JUMP into STEM Experience

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Abstract

The JUMP into STEM is an online building science competition for undergraduate and graduate students at U.S. colleges and universities launched by the Oak Ridge National Laboratory. The program recognizes the need of increasing the number of graduates from building science programs to cover workforce gaps in buildings specializations. Therefore, the initiative seeks to inspire the next generation of building scientists. The author of this paper became a member of the Professor Team for the 2022-2023 Program Challenges by implementing a project development activity in the graduate course MENG 5318 – HVAC. Four teams of four students participated in the challenge. The challenge topics were “It’s Electric,” “Curb Your Carbon,” and “Sustainable and Resilient.” Students in the course participated in the Curb Your Carbon challenge. The project ideas proposed by the instructor were in the topic of Evaporative Cooling. The project ideas were an opportunity for students to put in practice the material learned in the course, as well as an opportunity to support and promote research initiatives within the university’s research program on Evaporative Cooling that the instructor is leading. All four teams submitted their projects to the challenge. Motivation and dedication to the project development proved that the experience was positive in all aspects, which is supported by the results of a survey applied after the projects were submitted to the competition.

Introduction

The U.S. Energy Information Administration¹ reported that, in 2022, the Residential and Commercial end-use sectors accounted for 40% of total energy consumption nationwide, with Industrial and Transportation sectors accounting for 33% and 27% respectively. This energy consumption reflects the importance of actions for energy reduction in buildings. The U.S. Department of Energy (DoE) is the executive department of the U.S. federal government that promotes and supports energy reduction in all sectors. Certain offices within the DoE and national laboratories lead efforts to reduce energy in buildings, specifically. The Building Technologies Office, a branch of the Office of Energy Efficiency and Renewable Energy, “develops, demonstrates, and accelerates the adoption of cost-effective technologies, techniques, tools and services that enable high-performing, energy-efficient and demand-flexible residential and commercial buildings in both the new and existing buildings markets”². The Department of Energy, through the Office of Energy Efficiency and Renewable Energy and National Laboratories, has programs that include competitions for Colleges and Universities as well as Kindergarten through High School^{3,4}. Competitions focused on building science includes the Solar Decathlon⁵, the Race to Zero!⁶, the Solar District Cup⁷, the Geothermal Collegiate Competition⁸, and Jump into STEM⁹.

Articles can be found that refer to competitions for students, with some focused on the technical

matters presented through the competition and others are focused on learning matters through the competition. The following references have been selected as examples of those focused on the learning experiences through competitions. As mentioned by Schuster et al.¹⁰ competitions are a popular means to engage students in design activities that extend beyond the curriculum. In their paper the key benefits to engineering undergraduate students are discussed and they highlight the advisor involvement as a key role in both project success and student learning throughout the process. Stewart and Willy¹¹ highlight the ways in which the continued participation in the Collegiate Wind Competition of the Department of Energy has allowed for an ongoing, enriching academic as well as co-curricular experience for students. Additionally, the competition seeks to meet the needs of providing a diverse and educated workforce prepared for a wide variety of tasks in the wind industry. Herrera-Limones et al.¹² suggest that the participation on the Solar Decathlon of the Department of Energy has led to transformations in teaching leading students to new, broader, and more holistic approaches to study, as well as new capabilities and skills. Amaral et al.¹³ conducted a worldwide survey to assess the performance of the Solar Decathlon competition. Among the several questions in their survey, two questions are of interest for this paper: (a) “If it were possible, would you like to compete again?” and (b) “In your opinion which is the main reason why you are satisfied with SD?.” For question (a) 88% responded “Yes” and for question (b) 66.3% of the students acknowledged satisfaction on “Innovation and Knowledge Generation” and 41.4% of the students acknowledged satisfaction on “Fostering Education.”

The JUMP into STEM competition

The JUMP (Join the discussion, Unveil innovation, Make connections, Promote tech-to-market) into STEM [9] is an online building science competition for undergraduate and graduate students at U.S. colleges and universities. The competition was launched by the Oak Ridge National Laboratory (ORNL) in 2015 aiming to motivate engagement in STEM field research and innovation through challenges sponsored by industry and the national laboratories. The competition is for students, but it requires the commitment of professors that become members of the Professor Team. Members of the Professor Team must incorporate at least one of the JUMP into STEM challenges into coursework as a course requirement with an associated grade. The organizer promotes five benefits for participating professors where, in the author’s opinion, these two are the most relevant: (1) “Form a connection for yourself and your students with the U.S. Department of Energy and its National Laboratories” and (2) “Make a meaningful impact on building science education.” A series of webinars are offered to members of the Professor Team and the students on what needs to be done, what is expected, deadlines, and instructions for submission of the challenges. As a prize for participating the website states, “This year’s top teams, professors, and sponsors are invited to participate in person during the Final Competition scheduled for January 26–27, 2023, at the National Renewable Energy Laboratory’s main campus in Golden, Colorado. Final Competition winners receive a 10-week paid summer internship at the National Renewable Energy Laboratory, Oak Ridge National Laboratory, or Pacific Northwest National Laboratory.”

The Challenges for the 2022-2023 competition

It’s Electric

“The objective of this challenge is to increase the electrification of U.S. buildings (residential, commercial, new, or existing). Student team solutions should lead to reductions in energy use

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and carbon emissions through electrification solutions, and students should emphasize reducing inequalities in obtaining technologies for identified stakeholder groups.”

Curb Your Carbon

“The objective of this challenge is to develop an innovative solution that will reduce carbon emissions from U.S. buildings (residential, commercial, new, or existing). Student problem statements can focus on embodied carbon, carbon sequestration and storage, and/or operational carbon emissions. Innovative solutions should lead to significant reductions in carbon emissions, and fewer inequalities in obtaining new technologies for identified stakeholder groups.”

Sustainable and Resilient

“The objective of this challenge is to develop novel technical solutions to improve the resilience and sustainability of the built environment and identify ways for each proposed solution to enable underserved communities to adapt, persist, and recover from extreme weather and persistent stress, such as those caused by climate change.”

Submission

The teams must submit their project online. A Word document template is provided which includes:

General information

- ✓ Project Name
- ✓ Team Name
- ✓ Collegiate Institution
- ✓ Team Mission Statement
- ✓ Team Member Biographies
- ✓ Diversity Statement

Project information (up to five pages)

- ✓ Background
- ✓ Problem Statement
- ✓ Solution
- ✓ Technology-to-Market Plan
- ✓ References (does not count toward five-page maximum)
- ✓ Appendix (does not count toward five-page maximum)

The unlimited number of pages in the Appendix becomes a key element for the holistic presentation of the project since only five pages are allowed in the project information section of the manuscript. Detailed information can be given in Appendix regarding assumptions, computations, simulations, and results.

The Course

The course in which the competition was implemented is the graduate course MENG 5318 – Heating, Ventilation, and Air Conditioning (HVAC). The course focuses mainly on psychrometric

processes, but covers also thermal comfort, design conditions, hydronic system, air distribution systems, and parameters defining thermal loads.

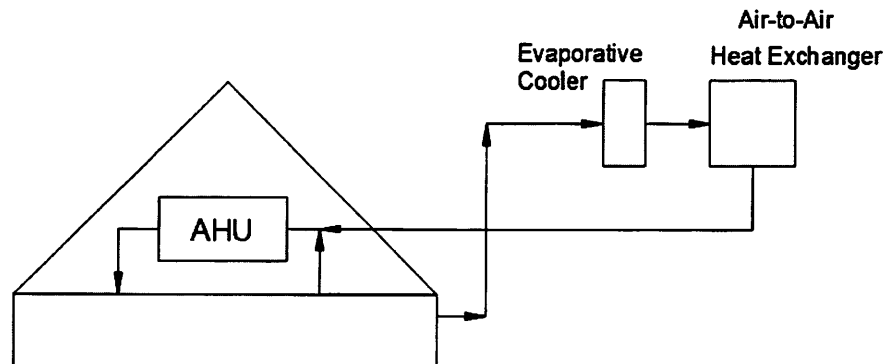
The cohort was composed of two female students and fourteen male students. Four teams of four students were created to participate with four different projects.

The Projects

The teams were asked to propose a topic for their project, otherwise the teams were to select one from the instructor's list. The topics on the instructor's list were all related to Evaporative Cooling since that is the research focus of the instructor. A brief description of the projects assigned to the teams are as follows:

Residential Direct Evaporative Cooling with Heat Recovery

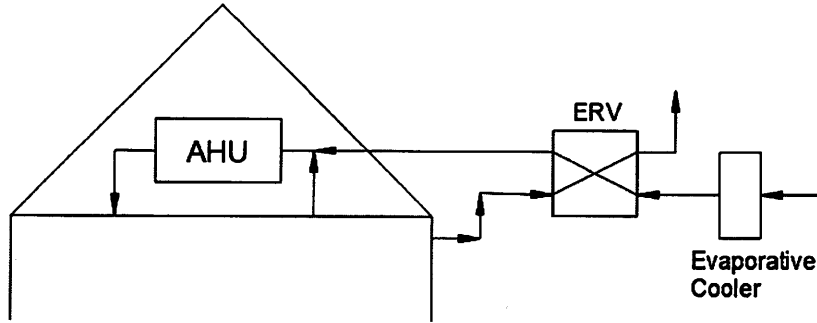
Houses need fresh air (ventilation) for indoor air quality (IAQ). To keep the pressure inside the house constant, the same amount of fresh air must be exhausted. The exhausted air, at the designed indoor conditions (low temperature and low humidity), is passed through an evaporative cooler to reach an even lower dry-bulb temperature. That air, exiting the evaporative cooler in the exhaust stream, is used to cool down the incoming outdoor air in the supply stream using an air-to-air heat exchanger before the supplied fresh air is introduced into the house. The cooled fresh air is then mixed with the return air at the air handling unit (AHU).



Residential Direct Evaporative Cooling with Energy Recovery Ventilator

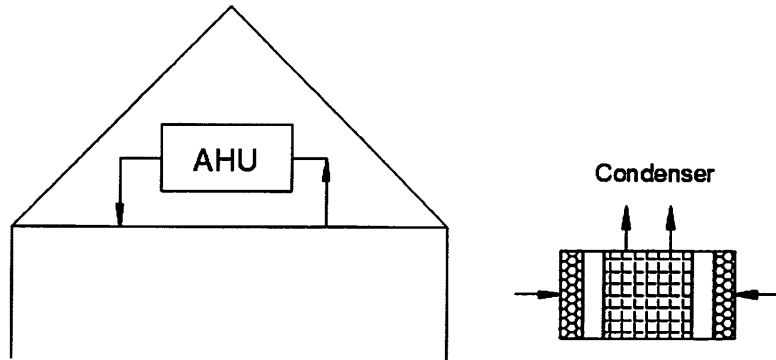
An Energy Recovery Ventilator (ERV) allows for sensible and latent heat transfer (energy/enthalpy) between two air streams without mixing them.

Houses need fresh air (ventilation) for indoor air quality (IAQ). To keep the pressure inside the house constant, the same amount of fresh air must be exhausted. Fresh air is passed through an evaporative cooler to decrease its temperature; however, it will gain humidity. To reduce its humidity before going to the air handling unit (AHU), the incoming air stream is passed through an ERV where the exhausted air, at the indoor condition (low temperature and low humidity), will remove some humidity from the fresh air as well as further lowering its temperature.



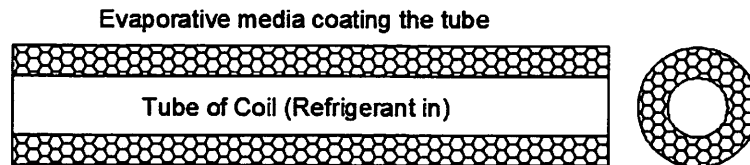
Evaporative Pre-Cooling of Air for Air Conditioner Condenser Coil

The condenser of an air conditioning takes outdoor air to remove the heat of the refrigerant to condensate it. If the air is passed through an evaporative media (evaporative cooler) the air used in the condenser would be at a lower temperature, increasing the efficiency of the air conditioning process.



Evaporative Cooling Condenser for Air Conditioners

The condenser of an air conditioning has coils with fins to increase the heat transfer between the metal of the coil-fins and the air. The heat transfer coefficient by convection is relatively low and that is why a large surface area is needed in condensers. If the coil of the condenser had a coated media used by evaporative coolers, to be used as an evaporative cooler, the water at the media would be in direct contact with the metal of the coil which should increase heat transfer. Also, because of the evaporative cooling effect, the water would be at a lower temperature than the air, which should increase the heat transfer process even more.



For comparison purposes of the four projects, the design indoor conditions and the cities for the outdoor design conditions were given. The indoor design conditions were 78°F and 50% for the dry-bulb temperature and the relative humidity, respectively. For the design outdoor conditions, the cities of Albuquerque, AZ and Las Vegas, NV were selected as representative of the mixed dry and hot-dry climate zones, as defined by the DOE Building America Program¹⁴. These climate zones were selected because the Evaporative Cooling technology is more effective in low humid climates.

As part of the project, students performed calculations that applied the concepts learned in the course. The economic analysis topic covered in the course helped the students to prepare the Technology-to-Market Plan section required with the submission.

Assessment

To present results of the JUMP into STEM experience in this course, the opinion of the instructor is given, as well as the results of a survey given to students after the submission of the projects to the competition.

Instructor

The large effort of the instructor to mentor the four teams through the development of the projects was compensated by the excitement and commitment of the students. The topics resulted in an experience for the students to apply thermal science concepts not only learned in the HVAC course but in other courses. All teams showed high expectations to be winners of the competition and almost all of them applied to the potential internship at one of the national laboratories offered by the organizer as part of the participation. To specify, the application was a component during the submission of the project to the competition.

Students

The survey had several questions to assess the opinion of the students on three specific aspects of the development of the projects as assignments on the course and the participation on the competition as follows:

Regarding the participation in the competition:

- Q1: Do you think the participation in the JUMP into STEM competition gave you additional motivation to work on the project?
- Q2: Do you think the participation in the JUMP into STEM competition offered you something beyond a grade for an assessment activity in the course?
- Q3: Do you think the participation in the JUMP into STEM competition was an easy process?

Regarding the topics of the given projects:

- Q4: Was the topic of your project in agreement with the course?
- Q5: Do you think the topic of the project reinforced the learning of material covered in the course?

Regarding the overall experience:

Q6: Was the project an enriching experience for you?

For all the questions the response options were as shown below to give a scale from 1 to 5, with 1 being the less positive perception and 5 being the highest positive perception:

Definitely Not



Definitely Yes

The results of the survey are presented in the figures below, in correspondence with the six questions mentioned previously.

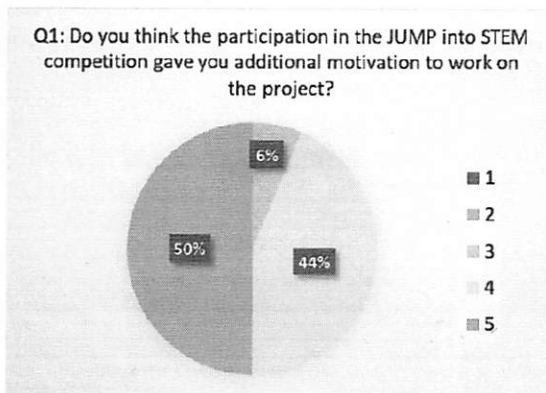


Fig. 1 Results Survey Question 1.

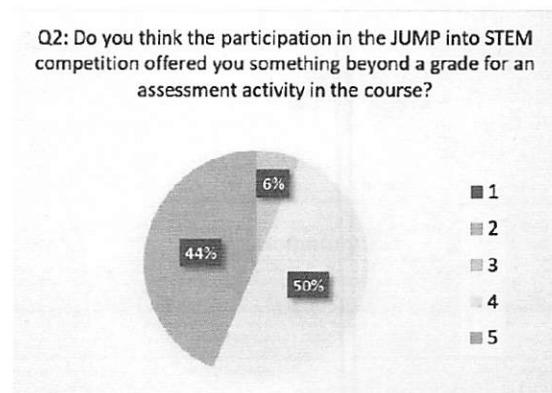


Fig. 2 Results Survey Question 2.

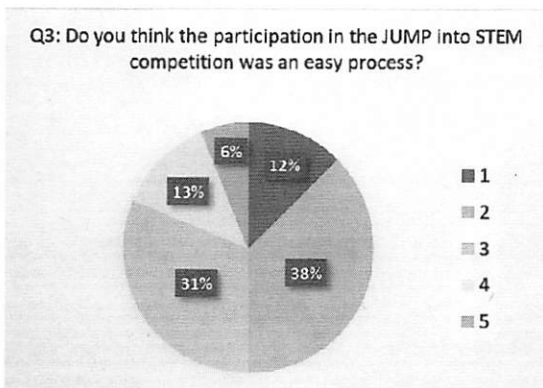


Fig. 3 Results Survey Question 3.

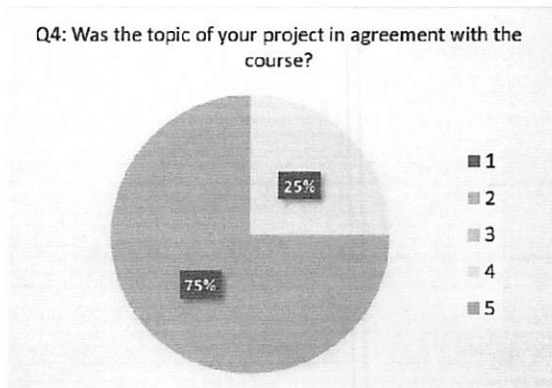


Fig. 4 Results Survey Question 4.

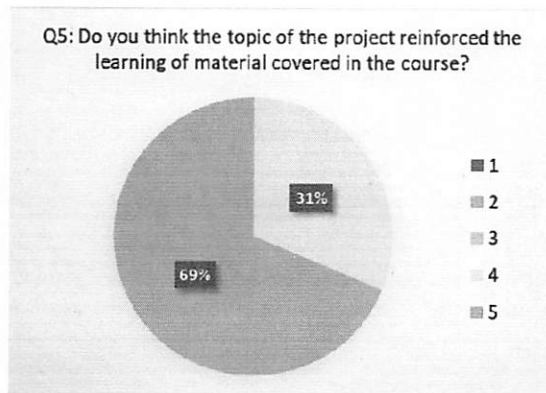


Fig. 5 Results Survey Question 5.

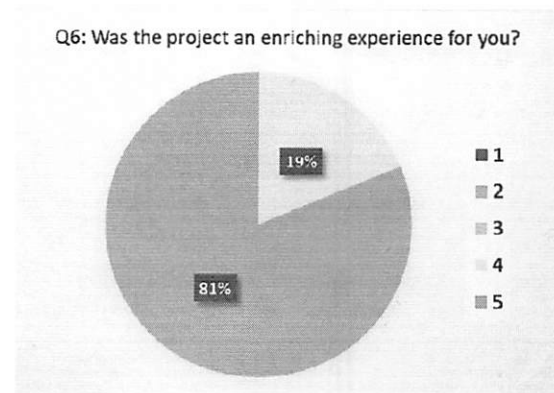


Fig. 6 Results Survey Question 6.

Conclusion

The JUMP into STEM competition was launched in 2018 by the Oak Ridge National Laboratory as a PILOT program and its continuity over five year has demonstrated the achievement of the goals of the program with benefits to academia through the participation of students and faculty. The assessment given by the instructor and students of their participation in the program, as well as the specific “Curb Your Carbon” challenge, shows that the implementation of the competition in the graduate course at The University of Texas at Tyler has been satisfactory. In particular, the instructor, and author of this paper, will continue participating in the competition. The additional motivation from students to work on the course assignment because it is part of a large competition is something worth to highlight. Additionally, the fact that 81% (Definitely Yes) and 19% (Yes) of the students considered the project to be an enriching experience ratify that the implementation of the competition in the course was a success for the benefit of the students and the course.

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Dr. Fumo currently serves as an Associate Professor of Mechanical Engineering at the University of Texas at Tyler. His research interests include energy in buildings with focus on HVAC systems, evaporative cooling and its application with membrane separation and liquid desiccants for air dehumidification. Dr. Fumo has also interest in engineering entrepreneurship.