Impact of Student Involvement in a Solar Wall Study for the State of Minnesota

Joseph Dobmeier, Joseph Gehrke, Matthew Simones, Patrick Tebbe
Mechanical & Civil Engineering Department
Minnesota State University, Mankato

I. INTRODUCTION

In 2008 Minnesota State University, Mankato (MSU) received a grant from the Minnesota Department of Commerce to study the reduction in carbon dioxide emissions achieved through the use of unglazed transpired solar collectors (UTCs), as requested by the Minnesota Department of Energy Security. From beginning to end, student contributions were vital to the success of the project. The UTC project was beneficial for the students involved because it allowed them to gain a much broader understanding of technological ventures than they would acquire from a typical lecture based approach alone. The deliverables for the project were performance characterizations of UTCs for multiple sites based on measurements of air temperatures and solar irradiance combined with component specifications for the buildings under study. This required extensive communication between the students and a number of industry actors including architects, HVAC engineers, equipment suppliers, construction contractors, and building operators. In addition, the students performed a literature review and interacted with faculty in order to develop a mathematical model representative of the UTC and its associated HVAC system. The model was designed to incorporate data and specifications collected from original design drawings, actual construction methods, equipment technical sheets, building management systems, and experimental instrumentation. Setup of the experimental rigs was a major undertaking in itself since temperature probes and data logging equipment had to be attached to the buildings under rather inauspicious conditions.

In this paper the UTC concept and research results will be briefly reviewed. Next, the contributions of students will be outlined along with assessments of the project's impact on students' comprehension of the role of research in the industrial enterprise. Finally, specific examples will be elaborated and conclusions drawn about the suitability of such projects to complement traditional lecture-based instruction.

II. PROJECT BACKGROUND

The UTC, as depicted in Figure 1, is a solar energy conversion technology which relies upon a dark colored perforated plate to absorb energy from the sun which is then transferred to incoming ventilation air. Doing so reduces the amount of fossil fuel consumption necessary to raise the ventilation air temperature to the building's supply air requirement. A study of the system involves many competing and complementary forces which do not lend themselves to a simplified solution. The intent of the MSU project was to determine experimentally how these systems perform in a Minnesota climate. The results have shown that UTCs are capable and appropriate for use in the Minnesota climate, with one site giving a heating season energy savings total of approximately 74 MBtu per square foot of collector area. The analysis also

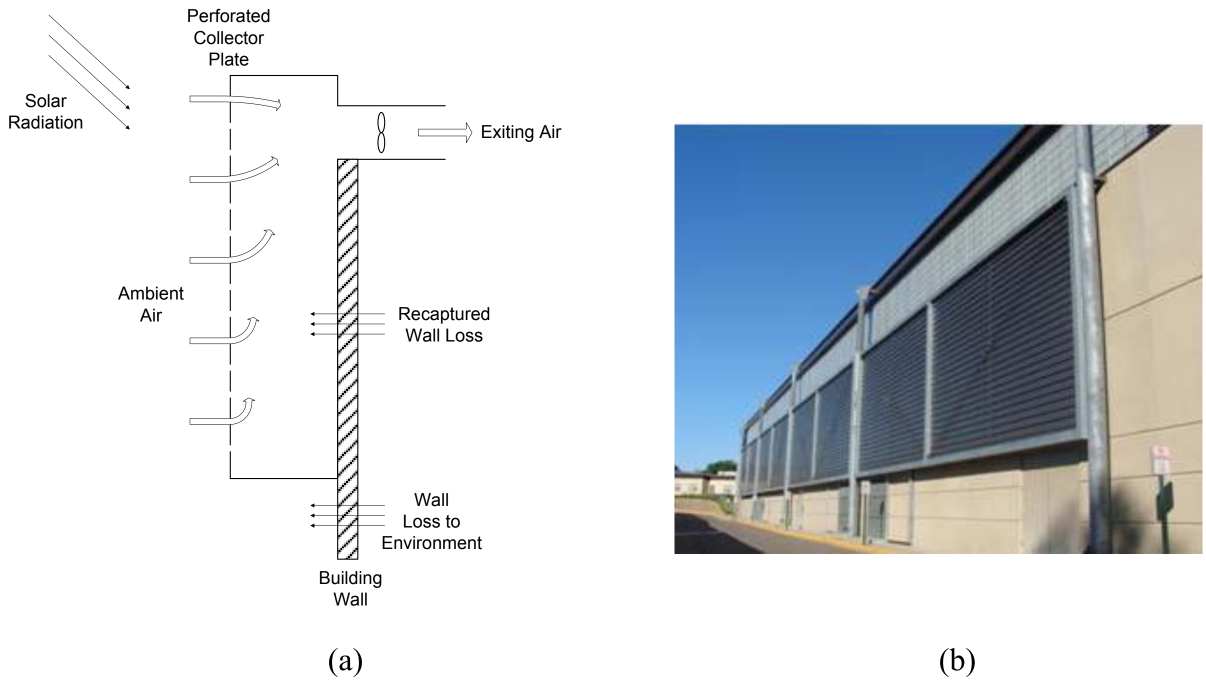

Figure 1: Examples of unglazed transpired solar collectors, (a) schematic and (b) installation at Breck School gymnasium.

detailed the separate contributions of active solar gain, recaptured building wall losses, and reduced building wall losses to the total energy savings.

Throughout the project there has been a strong focus and reliance on the assistance of student researchers. Several of these students have worked on the project for multiple semesters, taking on new tasks as their experience has grown. The research group throughout has been multi-disciplinary with Physics and Mechanical Engineering faculty and students. Undergraduate and graduate level students have also worked together. It was quickly found that scheduling issues for the repeated on-site visits would make it difficult for faculty to personally oversee all activities. Therefore, a process of peer mentoring was relied on with more experienced students leading the development of new students on the project. As students rotated off the project (due to graduation or other responsibilities) efforts were made to ensure that new students were fully trained by the time they would need to take over tasks.

III. PROJECT TASK BREAKDOWN

The first task performed for this project was a literature review. Students extensively searched journal articles from the campus library and online databases. While this is a required component for any graduate thesis, it was a novel experience for the undergraduates involved. The selected articles were archived by the students on a website under the campus domain to facilitate information sharing among team members. A review paper was then written which summarized the material and was included on the same website. This involved reviewing a number of published graduate theses, identifying assumptions, and discussing these with faculty.

I started on the UTC project during the summer after my junior year as a mechanical engineering student. At the time I was anxious to apply my knowledge of thermo/fluid sciences and mechanical design toward a real world application/engineering project, as well as learn more about renewable energy. The UTC project provided that experience allowing me to gain knowledge in passive solar energy systems and experience in conducting experimental research. Overall I feel fortunate to have the opportunity to be part of this project. I have learned more than I imagined at the beginning of the project and I have already applied some of these skills toward my graduate research.

-Student Researcher

Next, an experimental plan was developed to obtain the required data. The primary component was off-the-shelf weather stations with sensors for air temperature and humidity, wind speed and direction, and solar irradiance. To facilitate data collection and storage the weather stations were equipped with wireless data transmitters. A key parameter was the air temperature exiting the collector. Since the majority of sites were not equipped to measure this the weather station was outfitted with extra temperature sensors for insertion in the ductwork exiting the UTC.

Visits to the sites then had to be coordinated for equipment setup. Weather stations were installed at three sites; two of which had extra temperature sensors placed in the UTC air duct to monitor outlet temperatures. This required additional planning and work to install the sensors in the proper positions along with the use of unfamiliar tools to complete the installation (i.e., a telescoping boom and scissor type aerial lift platform used to route wiring and install sensors). An important aspect of this was proper safety training and the use of safety equipment.

One of the sites also incorporated a temperature profile measurement system consisting of eighteen thermocouples along with a separate data logger. This system measures the surface and interior temperatures of the wall. The thermocouples were installed in two 3x3 arrays, one on the surface of the collector and one close to the building wall. They were then connected to the data logger where temperature data was stored. Each sensor was mounted in a custom made mount designed to be inserted where existing connectors already existed (to minimize additional damage to the wall).

Two other students and I had to install eighteen thermocouples and wiring on the UTC at Breck school. Basic hand tools and a lift was all that was required to install the sensors, but it took us two trips over a period of a week to complete the installation because the weather was not cooperative on the days we worked. It was a combination of rain and snow the first day. The lift used to install the thermocouples somehow got moisture inside the control. This caused the hoist to stop working and it wasn't able to get repaired until the next day. Because of this we had to plan a second trip up to Breck to finish the installation. This day was also a combination of rain and snow which made the overall installation go a lot slower than planned. This goes to show that no matter how much planning goes into a project there can always be those unexpected things that can slow you down. This experience has shown me that the best you can do in these situations is accept that things didn't go as planned and just keep moving forward.

Student Researcher

Finally, each data logger was configured and initiated through the use of software available from the manufacturer. The software was downloaded to a laptop which then functioned as an interface to the data logger hardware. The design and installation complemented the conventional instruction the students received in Experimentation and Machine Elements classes and provided unique challenges which are difficult to duplicate in a classroom setting.

Once the equipment was installed, data collection from the sites could begin. Data from the weather station sensors was easily collected because it was all transmitted wirelessly to a web server. From there the data could be conveniently downloaded for analysis. Data collection for the thermocouple array was much more complicated. Since the data logger for the array didn't come with wireless capabilities, it necessitated manual, on site, downloads to a laptop. Also, the capacity of the logger's battery pack (which consisted of twelve size D batteries) limited the collection interval to a maximum of two weeks. This required trips to be made every other week or sooner to collect the data and install new batteries. In spite of this drawback, the data logger worked well and provided the students an excellent experience with collecting data in the field. It also provided a good opportunity for students to practice time management and communication skills (the students needed permission to access the data logger because it was on the roof of the Breck School's gymnasium).

> *Previously I had no experience working with specialized software for experimental data collection. On top of that, I never had any experience with this type of data logging system (standalone systems). Working on this project gave me invaluable experience with downloading data from a data logger and using software that can program and communicate with the data logger. It also made me conscious of the types of data logging systems that are available, for future reference.*
>
> *Student Researcher*

To facilitate data analysis, building and equipment specifications were gathered for all the sites. To achieve this, the students' first point of contact was the building operators. They provided information about the architects, design engineers, and construction contractors involved. Unfortunately, contacting these people proved to be one of the biggest challenges of the project. Issues such as personnel no longer being employed with their respective firms or being too busy with other projects to help seemed to be the norm. Were it not for the fortunate circumstance that multiple MSU alumni (who went out of their way to help) happened to be employed with the firms, the project could easily have been stalled. Building operators were also able to provide many original design documents and specifications when other avenues were exhausted. Needless to say, the students gained valuable experience from both successful and unsuccessful communication attempts. The importance of professional networking was made strikingly obvious. Furthermore, the influence of economic factors became apparent while requesting information. In some cases, industry partners initially appeared cooperative but were simply too overworked to provide much assistance. From the students' perspective, this was the least engaging aspect of the project.

In addition to specifications, building operators assisted with data collection from their own energy management systems. Students worked closely with them to determine what their systems were capable of measuring, how to best exchange data, and in what format the data would be provided. This phase of the project gave the students an intimate look at actual buildings and their environmental control systems. Concepts from courses such as Air Conditioning and Refrigeration, Automatic Controls, and Experimentation Labs were applied to understanding the practical implementations. While interacting with the operators, students were exposed to alternate viewpoints on the systems they have been learning to design.

> *Examining the physical processes at work in the system and relating them back to theoretical descriptions presented in class was a great opportunity to apply the knowledge I have attained. I found it interesting to see how concepts which are given separate treatment during instruction are very interrelated in practice. The lines were blurred between what I had hitherto considered separate problem domains, i.e., using psychrometric principles to define properties of moist air within an otherwise textbook heat transfer problem.*
>
> *Student Researcher*

Following data collection, an analysis was performed. The purpose of the analysis was to determine the amount of energy saved from drawing air through the collector plate, as opposed to ambient outside air. The relative contributions of each component were also determined: active solar gain, recaptured wall losses, and reduced wall losses. This was accomplished by defining a physical model of the system that was utilized, along with the collected data, to calculate the variables of interest. Defining the model drew upon knowledge gained in junior level courses such as Fluid Mechanics, Heat Transfer, and Thermodynamics as well as the electives: Air Conditioning and Refrigeration and Thermal/Fluid Systems Design. Extensive use was made of the spreadsheet program Microsoft Excel combined with programming written in Visual BASIC for Applications. During coursework, particularly laboratory sections, simple charts and calculations are made with Excel but the scope and complexity of this project went far beyond what is typically expected in an undergraduate course. Overall, the individual tasks performed in this phase of the project deviated from traditional classroom instruction the least; yet it was also the most holistic, in terms of technical content, of all the phases.

One of the deliverables for this research project was a journal submission to ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers). First, all the information on the project was pulled together and organized. Summaries for all the test sites were written which included background information, UTC characteristics and installation details, operation of the energy management system, and a review of the sensors used and their specifications. The analyzed data was presented in plots and tables and an overview of the results was written to explain the data and the modes in which UTCs reduce energy usage. This information was then compiled into a draft paper that was reviewed and edited several times before it was submitted to ASHRAE. The paper will be peer reviewed and published as an ASHRAE conference journal article (that includes the names of all the students involved in the project) which can be accessed by engineers worldwide. This gives the students a concrete way to show the work that they completed on the project. Besides getting their names on a paper that will be published by a national organization, this portion of the project helped the students strengthen their skills in time management, proof reading and editing papers, and meeting deadlines.

Working on ASHRAE paper has benefited me in several ways. Learning about the attention to detail required to write for a professional journal was truly eye opening. A large amount of time was spent on making sure the text was in the proper font and size, plots and tables were in the mandatory format, and just the right amount of information was included in the paper because there were restrictions on how long it could be.

Student Researcher

IV. SUMMARY

Most engineering programs employ student outcomes which include, or are modified from, the standard ABET a-k outcomes. The student impact of this research project can be judged by determining the outcomes that have been addressed. An examination of student activities reveals that all of these outcomes have been touched on by the research project.

Overall, this project was an invaluable experience to the students involved. The students were unanimous in the opinion that the project was able to tie together diverse elements of their education. It has helped to reinforce concepts and skills that were learned in the classroom. Using mathematical equations to analyze data; applying thermodynamic and heat transfer concepts to understand flow rates, temperature differences, and energy transfers; and incorporating soft skills such as spell checking, paper formatting, and use of proper grammar are all examples of learned classroom skills used on this project. More importantly it has given the students experiences that are impossible to duplicate in the classroom. Communicating with people in industry, coping with unexpected problems, and working with specialized tools are just a few examples. This research project has exposed students to a renewable energy source and the significant economic benefits of using energy wisely and efficiently. It also gave the students an idea of the importance that further development of renewable energy technologies has for society. With these newly gained experiences, the students involved will now be better prepared to face the many challenges that they will face in school, in their careers, and beyond.

Acknowledgments

This work has been supported by a grant from the State of Minnesota through the Minnesota Office of Energy Security. Additional students who contributed to this grant work were Arbin Timilsina, Bradley Wiyninger, and Kamal Mohsin.

BIOGRAPHICAL INFORMATION

JOSEPH DOBMEIER is a graduate student in mechanical engineering at Minnesota State University, Mankato.
JOSEPH GEHRKE is a senior undergraduate in mechanical engineering at Minnesota State University, Mankato.
MATTHEW SIMONES is a graduate student in mechanical engineering at Minnesota State University, Mankato.
PATRICK TEBBE is an Associate Professor of mechanical engineering at Minnesota State University, Mankato.