Using an Article in a Sophomore Engineering Science Class to Boost Life-long Learning Confidence

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Abstract

Sophomore-level engineering classes often do not require students to find properties or processes in the literature, as advanced engineering courses do. Using the literature to find information is often considered part of fulfilling ABET outcome i: a recognition of the need for, and an ability to engage in, lifelong learning. The design project in a sophomore-level course was based on an article in *Chemical Engineering Progress*, and students were surveyed about confidence in ability to understand similar articles before, during, and after completing the design project.

Optimizing an Organic Rankine Cycle by Bourji and Winstead (*CEP*, January 2013, 35-39) covers a basic Rankine cycle and a Rankine cycle with a form of regeneration, which are both covered in introductory thermodynamics courses. Students who understand the course material should understand the thermodynamics of the paper. The participants read the article and answered a questionnaire three times during the semester: before Rankine cycles had been covered in class, just after the homework assignment on Rankine cycles with regeneration was due, and just after the project based on the article was due. The questionnaire asked about understanding the article, ability to follow the thermodynamic modifications of the article, and ability to reproduce the thermodynamic calculations of the article. All three of these improved as the students learned the material in the course and worked with it through homework and the design project. Confidences in ability to understand engineering principles and to reproduce calculations of similar articles also improved during the study and were probed with separate questions. This study showed that lifelong learning can be encouraged in lower-level courses with the appropriate selection of articles.

Introduction

When *CEP* published an article on organic Rankine cycles and included flowsheets[1], a design project was created for an introductory thermodynamics class that required the students to reproduce the calculations presented in the flowsheet as well as create their own modified cycle. A research question associated with this project is whether the in-depth work with the article increases student confidence in lifelong learning skills.

Criterion 3i of ABET's Engineering Accreditation Commission is that students will have "a recognition of the need for, and an ability to engage in lifelong learning"[2]. The attributes of a lifelong learner include "a sense of personal agency"[3]: students must feel that they can successfully use the information available to them to learn something new. Mourtos states that students must be able to "read critically and assess the quality of information"[4], and this project had the student verify the calculation of the turbine and pump powers given in paper using the given flowsheet information. Another skill in Mourtos's work is "synthesize new concepts by making connections, transferring prior knowledge, and generalizing". The students were asked to add a closed feedwater heater to the article's Rankine cycle, which made a connection between their coursework and the article and transferred the prior knowledge from the course to the design project. The students were also asked to examine different pressures for that feedwater heater and recommend the best design from among the paper's Rankine cycle, the paper's Rankine cycle with a regenerator, and the students' own Rankine cycles with feedwater heaters. These pressure designs and recommendation asked the students to generalize. The design project engaged the students in skills that they need for lifelong learning, but did the project increase their confidence in their lifelong learning skills?

It could be argued that *CEP* is really a magazine instead of a journal, but the students may be intimidated by it just as much. As bachelor-level engineers, they are likely to start with *CEP* and move deeper into the literature as needed. They need confidence that they can understand the articles of *CEP* as well as those of journals.

Methods

Participants were recruited from a course taught by the researcher. No extra credit was given for participation, and participation was voluntary. Paper surveys (Appendix A) were distributed at the end of three lectures. The surveys asked basic demographics questions as well as how many journal articles that student had read before and in what context. The content questions asked how well the student understood the article, could follow the thermodynamic modifications of the article, and reproduce the calculations. The survey also asked if a student finishing the course should be able to understand the article and about the student's confidence in understanding and reproducing calculations of similar articles. The last two questions, confidence about similar articles, were considered to be the primary indicators of confidence in lifelong learning abilities. These content questions used a 5-point Likert scale with 1 being a low response and 5 being a high response. A question on the last survey asked if any of the student's other courses that semester had used a journal article.

The course grader collected the surveys, coded the participants, and entered the survey data. The survey was given three times during the semester: before Rankine cycles were covered in any coursework (the pre survey), after the homework assignment on Rankine cycles with regeneration was due (post-HW survey), and after the project was due (post-project survey). Pre and post-HW surveys were compared with a one-tailed paired t-test, and post-HW and post-project surveys were compared the same way. The confidence of students who had previously read journal articles was compared to those who had not.

Between the pre survey and the post-HW survey, the students attended lectures on Rankine cycles with modifications and did two homework assignments with problems on Rankine cycles with modifications. Attendance was required, and the lectures were fairly traditional with a daily group quiz to break up the lecture material. Between the post-HW survey and the post-project survey, the only student interaction with the material was through their design team work on the project. The design project (Appendix B) was a group project with teams formed by the professor using Team-Maker[5] with similar schedules and disparate GPAs and majors. The project was the only work the team did together. Teamwork evaluations were done by CATME[5] twice during the project.

Results and Discussion

Survey responses were collected from 34 different students over the three surveys. There were 39 possible participants. Demographics of the participants are given in Table 1. The majority of the participants were male petroleum engineering majors who were taking the course on-track in the fall of the sophomore year. [10% of the undergraduate enrollment for the entire university is petroleum engineering majors, so the high number of petroleum engineering participants is not surprising.] One junior and one senior reported being in their first semesters at the university, so they may have been transfer students.

Table 1. Demographics of survey participants

	Number of participants	Percent of participants
Female	12	35
Male	22	65
Major		
Chemical engineering	7	20
Mechanical engineering	6	18
Petroleum engineering	21	62
Level		
Freshman	1	3
Sophomore	30	88
Junior	2	6
Senior	1	3
Semester at this university		
First	2	6
Third	28	82
Fourth	2	6
Fifth	2	6

The participants were surveyed about the number of journal articles they had read previously and if those were for a course or for undergraduate research. Details are given in Table 2. Almost half (15 of 34) of the participants had read a journal article before. Five of the students had done undergraduate research, but only one of them had read a journal article with that research work. It is surprising that student researchers had not encountered a journal article, even if they had been in research groups for a month or two. Only six students reported a previous course using a journal article. Two of those students who had read a journal article in a previous course were upperclassmen, and how early the journal articles were used is unknown. The majority of the students who had read a journal article apparently did so out of their own interest. Students who did have previous article-reading experience tended to rate the survey questions lower, although it is doubtful that any differences are significant. Although nearly half of the participants had read a journal article before, a sophomore course still represents a good opportunity to introduce technical literature.

Table 2. Previous journal experience

Had read an article in	Number of participants	Percent of participants
Chemical Engineering Progress	4	12
Mechanical Engineering	2	6
Journal of Petroleum Technology	6	18
Undergraduate research experience		
	No	29
	Yes	5
Journal use in previous course		
	No	27
	Yes	6

Nineteen participants completed both pre and post-HW surveys. As expected, the survey responses were higher for all six research questions after the students had worked homework on the material than before the material was covered at all in the course. The responses were significantly higher for only three research questions, as shown in Table 3. The students started off lower in their confidence to reproduce the calculations of the article and of similar articles, so the scores for those two questions had the most room for improvement. Lectures and a homework assignment did greatly boost their confidence in being able to do the calculations of this article. It is interesting that confidence in performing calculations of similar articles was boosted almost as much. The only other significant change was that the students agreed more that the article was written at a level appropriate for students completing the course, as was written at the top of the survey.

Table 3. Paired t-test results for pre surveys and post-HW surveys, N = 19

Question	Pre mean	Post-HW mean	One-tailed probability
1. understand article	3.37	3.42	0.33
2. follow thermodynamics	3.16	3.37	0.11
3. reproduce calculations	2.71	3.37	0.0017
4. article at ES 3053 level	3.63	3.89	0.028
5. understand similar article	3.26	3.42	0.13
6. reproduce similar calculations	2.71	3.26	0.0061

The post-HW and post-project surveys were completed by 18 participants, with the t-test results presented in Table 4. The means for the post-HW surveys are slightly lower in Table 4 than in Table 3 because the two participant sets overlap for only 17 participants. Again, the average responses to all six questions increased after working the design project, as expected. The increase is significant for all six questions for post-HW to post-project. The extra work done with the article material during the project made a big difference in the participants' confidence in working with the literature.

Table 4. Paired t-test results for post-HW surveys and post-project surveys, N = 18

Question	Post-HW mean	Post-project mean	One-tail probability
1. understand article	3.33	3.94	0.00086
2. follow thermodynamics	3.28	3.83	0.00013
3. reproduce calculations	3.22	3.67	0.044
4. article at ES 3053 level	3.83	4.17	0.015
5. understand similar article	3.33	3.72	0.0074
6. reproduce similar calculations	3.17	3.56	0.0074

Working the project seemed to have a greater effect on the participants' confidence than lectures and homework. Table 5 compares the increase in the means of the survey questions between the pre survey and post-HW survey to those for the post-HW to post-project survey. Table 5 shows that working on the projected increased the survey means more than the homework and lecture for all but the "reproduce calculations" and "reproduce similar calculations" questions. Given the literature on the effectiveness of active engagement with material in student learning, it is not surprising that the effectiveness of active engagement carries over to confidence in lifelong learning skills.

Table 5. Increases in means of survey responses due to lecture and homework compared to increases due to project

Question	Lecture/Homework	Project
1. understand article	0.05	0.61
2. follow thermodynamics	0.21	0.55
3. reproduce calculations	0.66	0.45
4. article at ES 3053 level	0.26	0.34
5. understand similar article	0.16	0.39
6. reproduce similar calculations	0.55	0.39

All of the fifteen students who answered the final question about whether any of their other classes had used a journal article this semester answered no. Combined with data presented earlier about use of journal articles in research and earlier coursework, sophomore-level courses offer a good opportunity for the first formal exposure to a journal article.

This design project was similar to two of the steps in the C.R.E.A.T.E. course[6]: Analyze and interpret the data and Think of the next Experiment. In the C.R.E.A.T.E. course, the students imagine that they are scientists interpreting journal articles so they can continue the research into the next step. In this project, the students checked the calculations of the article so they could continue with another design and compare all three. Participants in this study showed an increase in their confidence in understanding literature, just as the students in the C.R.E.A.T.E. course. Students in the C.R.E.A.T.E. course showed other improvements since it is a much larger intervention with students, but this one design project fits seamlessly into existing courses and still improves student confidence with articles.

Although this design project was done with a sophomore introductory thermodynamics course, other similar articles exist for thermodynamics as well as fluid mechanics, heat transfer, and separations[7-12]. Students in these junior-level courses would likely benefit from a boost in confidence after working a design project based on these articles as well.

Conclusions

Student confidence in understanding and reproducing calculations of a journal article was surveyed before the topic was covered in the course, after completing homework on the topic, and after completing a design project based on an article. Participant confidence in ability to do calculations in articles and that the article was written at the student's level were the only survey questions that increased with the lectures and homework. The means to all six survey questions increased from the post-homework survey to the post-project survey, including participant confidence in understanding articles and following the thermodynamics. Basing a sophomore design project on an article was an effective way to increase student confidence in lifelong learning ability.

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Appendix A
Questionnaire

SKIP THIS PAGE IF YOU COMPLETED IT WITH THE FIRST SURVEY.

Please fill in the blank or circle your response.

1 How many articles have you read from the following?

_______*Chemical Engineering Progress* (AIChE's magazine)

_______*Mechanical Engineering* (ASME's magazine)

_______*Journal of Petroleum Technology* (SPE's magazine)

2 How confident are you that you can read an article in one of the magazines above and understand it?
Completely not confident   not confident   ambivalent   confident   very confident

3 Have you done any research at the college level? ______ Yes ______ No

If so, for how many months? ___________

How many journal articles related to your research have you read, and what journals were they in?

____

4 Have any of your previous science, math, or engineering courses used a journal article as part of the course material? ______ Yes ______ No If so, please list the journals and courses.

____

5 Gender: _____Male ______Female

6 Major
______Chemical Engineering
______Electrical Engineering
______Engineering Physics
______Mechanical Engineering
______Other
______Petroleum Engineering

7 Level
_____Freshman _____Sophomore _____Junior _____Senior

8 Semester at TU 1, 2, 3, 4, 5, 6, 7, 8, 9 or more

Read the attached article on Organic Rankine Cycles, which is aimed at BS-level working chemical engineers. When you have completed ES 3053, you should have all of the thermodynamics required to understand this article.

1 Rate your understanding of the article

Extremely poor	poor	acceptable	good	great

2 Rate your ability to follow the thermodynamic modifications discussed in the article

Extremely poor	poor	acceptable	good	great

3 Rate your ability to reproduce the thermodynamic calculations presented in the article

Extremely poor	poor	acceptable	good	great

4 Is this article written at a level someone who has successfully completed ES 3053 can understand?

Definitely not	no	maybe	yes	definitely yes

5 Based on this article, how confident are you that you could understand the engineering principles in similar articles in *Chemical Engineering Progress*, where this article was printed, or similar articles in *Mechanical Engineering* or *Journal of Petroleum Technology*?

Completely not confident	not confident	ambivalent	confident	very confident

6 How confident are you that you could reproduce calculations in similar articles?

Completely not confident	not confident	ambivalent	confident	very confident

One additional question for the last survey:

Have any of your science, math, or other engineering courses **this semester** used a journal article as part of the course material?

If so, please list the journals and courses.

Appendix B

To: ES 3053-04 Teams
From: Dr. Ford
Re: Optimizing an Organic Rankine Cycle
Date: Oct. 29, 2014

Chemical Engineering Progress, the magazine of the American Institute of Chemical Engineers, published an article on Optimizing an Organic Rankine Cycle by Ali Bourji and Alan Winstead in January 2013[1]. This article discusses the optimization of a Rankine cycle with propane as the working fluid. An interesting difference between a steam Rankine cycle and an organic Rankine cycle is in the high temperature heat exchanger. Since propane is supercritical in the high pressure part of the cycle, the propane does not boil in the high temperature heat exchanger, as steam does. After optimizing the simple Rankine cycle, the authors then optimized the cycle with a "recuperator", which is a variation of the regenerative cycle with a closed feedwater heater with a trap. In the regenerative cycle, a fraction of the steam is extracted at an intermediate pressure from the turbine and used to heat the fluid leaving the pump. A recuperator is the regenerative cycle in the extreme that *all* of the stream *leaving* the turbine (not at an intermediate pressure) goes to the heat exchanger with the pumped liquid. Your team's task is to design cycles with a closed feedwater heater and compare them to the cycles in the paper.

Start by verifying the work in the paper. Figure 2 states flowrates, temperatures, and pressures of the streams as well as the power and heat transfer rates for the basic Rankine cycle. The listed "vapor fraction" is not the same as quality, so that row may be ignored. [In chemical engineering process simulators, the vapor fraction is 1.0 for saturated vapor *and* superheated vapor and 0.0 for saturated liquid *and* compressed liquid.] Check that their power and cycle efficiency calculations are correct. If you get discrepancies larger than 5%, attempt to explain the differences.

Next, add a closed feedwater heater to the cycle in Figure 2. Your team will create one design for each team member, with a different feedwater heater pressure for each member. Calculate the extraction fraction for each design. Make a graph of cycle efficiency and net power production versus feedwater heater pressure for your designs. Use a sufficiently wide range of extraction pressures to see an effect on cycle efficiency. You do not need to optimize the cycle as the article did.

Third, estimate the equivalent annual operating cost of your designs and of those in the article. Appendix 1 has equations for estimating capital costs, utility costs, and the equivalent annual operating cost.

Lastly, write a memo to me that discusses the project. A memo is an informal communication, such as this one, that starts with a To/From/Re/Date block at the top. Every team member should initial the From line. A suggested outline of the memo includes five paragraphs. The first paragraph should be a brief overview of the design project. Discuss whether or not you were able to verify the calculations in the article in the second paragraph. The third paragraph should cover your feedwater heater cycles and include the graph of cycle efficiency and net power production versus feedwater heater pressure. A table of the various costs should accompany the economic discussion of the fourth paragraph. The third and fourth paragraphs might be small enough to combine. Your team should make a recommendation to construct one of the designs (original, with recuperator, or one of your feedwater heater designs) in the last paragraph. You should explain why you have chosen the recommended design. The body of the memo should be only 1 or 2 pages. Calculations and design diagrams should be included in the appendix. Diagrams may be hand-drawn if you use a ruler, or you may find The Engineering ToolBox Process Flow Diagram drawing template[3] or Insert Shapes in Microsoft Word useful.

According to the syllabus, the design project is due Friday, Nov. 14. The memo will be graded according to the point distribution in Appendix 2. Since writing is 50% of the grade, you may wish to take your memo to the Wallace Writing Center on the 3rd floor of the McFarlin Library for a consultation. Tables and figures in Chapter 2 of our textbook will give you examples of proper formatting.

References

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3. PFD – Process Flow Diagram – Online Drawing, The Engineering ToolBox, http://www.engineeringtoolbox.com/pfd-process-flow-diagram-online-drawing-d_1640.html, accessed Oct. 17, 2014.

Appendix 1 Cost Estimation Data[2]

Note: The numbers following the attribute ($\dot{W}$ = power, for example) are the minimum and maximum available values for that attribute, in the given units. For a piece of equipment smaller than the minimum, use the minimum attribute value to compute the cost. For a piece of equipment larger than the maximum attribute, extrapolation is possible but inaccurate. To err on the side of caution, you should use the price for multiple, identical smaller pieces of equipment.

Pumps $\log_{10}(\text{purchased cost}) = 3.4 + 0.05\log_{10}\dot{W} + 0.15[\log_{10}\dot{W}]^2$

$\dot{W}$ = power (kW, 1, 300)

Heat Exchangers $\log_{10}(\text{purchased cost}) = 4.6 - 0.8\log_{10} A + 0.3[\log_{10} A]^2$

A = heat exchange area (m^2, 20, 1000)

Estimate the area based on $\dot{Q} = UA\Delta T_{LM}$ with

U = 5000 $W/m^2\cdot{}^oC$ for a feedwater heater

U = 500 $W/m^2\cdot{}^oC$ for the condenser

U = 25 $W/m^2\cdot{}^oC$ for the high temperature heat exchanger

$$\Delta T_{LM} = \frac{(T_{hot\_in} - T_{cold\_out}) - (T_{hot\_out} - T_{cold\_in})}{\ln\left(\frac{(T_{hot\_in} - T_{cold\_out})}{(T_{hot\_out} - T_{cold\_in})}\right)}$$

Turbine $\log_{10}(\text{purchased cost}) = 2.5 + 1.45\log_{10}\dot{W} - 0.17[\log_{10}\dot{W}]^2$

$\dot{W}$ = power (kW, 100, 4000)

Utility Costs

Electricity $0.06/kWh and Cooling Water $0.354/GJ

Equipment Cost Factors

Total Installed Cost = Purchased Cost (4 + pressure factor (PF))

Pressure	< 10 bar, PF = 0.0	does not apply to turbines since their cost equation
(absolute)	10 - 20 bar, PF = 0.6	includes pressure effects
	20 - 40 bar, PF = 3.0	
	40 - 50 bar, PR = 5.0	
	50 - 100 bar, PF = 10	
	> 100 bar, PF = 15	

The Equivalent Annual Operating Cost (EAOC, $/y), is defined in Equation 1.

$$EAOC = 0.20\, CAP + AOC - R \qquad (1)$$

CAP ($) is the total installed cost for the pump, heat exchangers, and the turbine,
AOC ($/y) is the annual operating cost, which is the utility cost for the condenser, and
R ($/y) is the annual savings from the electricity generated.

The factor 0.20 includes a 15% rate of return on investment and a ten-year plant life.

Appendix 2 Design Project Gradesheet

Team ______________________

Members:

Writing (generally -1 point per error)

/ 5	Spelling
/ 5	Grammar
/ 5	Flow/logical connectedness/clarity
/ 5	Proper content in proper places (Appendix material in appendix, etc.)
/ 5	Formatting (Is it a memo? Table labeled? Graph labeled? Etc.)
/25	Writing Total

Technical

/ 7	Article verification
/ 8	Regenerative designs
/ 8	Economic analysis
/ 2	Recommendation
/25	Technical Total

/50 Project Total