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A Student-Centered Active Learning Approach to Teaching Grant Proposal Writing in a Ph.D. in Engineering Education Program*

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Nearly all published literature on grant proposal writing focuses on suggesting best practices for, or providing general guidance on, grant proposal writing (i.e., what a grant writer should do and should not do), rather than on pedagogy (i.e., how to teach grant proposal writing). To fill this gap, a student-centered active learning approach to teaching grant proposal writing is developed in the present study. This approach combines three types of active learning activities: think-pair-share discussions and reflections, mock panel review, and student development of a full proposal. This approach was implemented and assessed in a grant proposal writing course in a Ph.D. in Engineering Education program at Utah State University. Questionnaire surveys were administered in two semesters to assess the effectiveness of this approach. The results show that, on a 5-point Likert-type scale with 1 representing the least effective and 5 representing the most effective, the mean scores of student responses are more than 4.00 for all three types of active learning activities. The mean scores on "student development of a full proposal" activities are the two highest mean scores in both semesters: 4.71 in one semester and 4.63 in another semester. This implies that the most effective method for students to learn how to develop grant proposals is learning by doing, i.e., each student develops a proposal of his/her own.

Keywords: grant proposal writing; students-centered active learning; pedagogy; Ph.D. in engineering education

1. Introduction

1.1 Importance of grant proposal writing

As competition for external funding becomes increasingly fierce in recent years nationwide, grant proposal writing receives growing attention at educational institutions. The importance of grant proposal writing is manifested in the following three aspects.

First, the ability to secure external funding plays a critical role in determining the tenure and promotion of a faculty member [1–3]. As Grose [1] pointed out that "in recent years the stakes have risen dramatically and junior faculty members are now expected to bring in wads of cash from day one, or risk not getting tenure." Given the fact that many junior faculty members are recruited from current doctoral students, it is important to provide doctoral students with early training and education on how to develop competitive grant proposals, so they can survive in strict academic environments later on.

Second, due to significant budget cuts at many educational institutions, external funding is crucial for curriculum reforms and laboratory improvements. Financial costs are involved in nearly every aspect of university/college business, ranging from updating laboratory equipment and instruments to compensating for faculty summer salary [4]. Currently, many educational institutions, especially public institutions, rely heavily on external funding to maintain daily operations and education quality. As future faculty members, doctoral students should be provided extensive training and education on grant proposal writing, so they can secure funding to enable curricular changes when they hold faculty positions.

Third, writing skills are among highly important communications skills that the Accreditation Board for Engineering and Technology (ABET) recommends universities and colleges to emphasize [5, 6]. Graduates with excellent writing skills, including excellent skills for grant proposal writing, are always reviewed favorably by both educational institutions and industry as well [7, 8].

1.2 Engineering students' lack of training in writing grant proposals

Unfortunately, the majority of engineering students lack fundamental training and education on grant proposal writing [8]. Their writing experiences are mainly obtained from undergraduate technical writing courses in the English department and/or communication intensive courses within their engineering curriculum [9–15]. The emphasis of these courses is to teach students how to write technical reports, theses, and essays, rather than how to write grant proposals. Even for graduate students, their

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proposal writing experiences are limited to writing thesis or dissertation proposals, not writing grant proposals. It is common knowledge that thesis or dissertation proposals are different from grant proposals in many aspects. For example, thesis or dissertation proposals do not involve such components as budget, budget justification, and a description of the Principal Investigator's qualification. However, nearly all grant proposals must include these three components. More important, as compared with thesis or dissertation proposals, a grant proposal typically has a page limitation that presents a great challenge for the proposer(s) to synthesize the major research findings from literature review and to present the research questions and methodologies in a clear and concise manner, so the proposal reviewers can quickly understand the contents of the grant proposal. In short, an excellent grant proposal writer is often an excellent thesis or dissertation proposal writer as well. Nevertheless, an excellent thesis or dissertation proposal writer is not necessarily an excellent grant proposal writer.

A PhD in Engineering Education program was recently established at Utah State University, the institution of the author of this paper. The goal of the program is to develop future faculty members who are able to carry out high quality educational research, understand modern pedagogical theories, and apply those theories to teach engineering courses. Typically, doctoral students in this program have had a BS and/or MS in an engineering discipline (such as mechanical engineering, civil engineering, and electrical engineering) before they enter the program. Because these doctoral students have already taken a variety of engineering courses in their BS and/or MS course of study, the PhD in Engineering Education course curriculum primarily consists of a variety of education courses, such as Foundations of Engineering Education, Evaluation and Assessments, Research Methods and Design, The Role of Cognition in Engineering Education, and Finance and Grant Writing. The majority of doctoral students in this program have no prior experience in developing either an engineering research grant proposal or an educational grant proposal. In an engineering research grant proposal, the object of study is non-human, such as a machine, a mechanical or electrical device, or a computer algorithm. In an educational grant proposal, the object of study is typically human, such as students, faculty, stakeholders, and the general public.

1.3 Objectives and uniqueness of the present study

The objectives of the present study are: 1) to develop a student-centered active learning approach to teaching a grant proposal writing course in the PhD in Engineering Education program, and 2) to assess the effectiveness of the approach on student learning outcomes.

The student-centered active learning approach developed from the present study combines three types of active learning activities: think-pair-share discussions and reflections, mock panel review, and student development of a full proposal. These activities will be described in great detail in Section 2 of this paper.

The author of this paper has performed extensive literature review using a variety of popular databases, such as the Education Resources Information Center, Science Citation Index, Social Science Citation Index, Engineering Citation Index, Academic Search Premier, the ASEE annual conference proceedings (1995–2011), and the ASEE/IEEE Frontier in Education conference proceedings (1995-2011). The results of extensive literature review shows that nearly all published literature on grant proposal writing focuses on suggesting best practices for, or providing general guidance on, grant proposal writing (i.e., WHAT a grant writer should do and/or should not do [such as 16–21]), rather than on pedagogy (i.e., HOW to teach a grant proposal writing course). The present study addresses pedagogy.

For example, Jackson [16] introduced his own experiences in developing two successful educational grant proposals submitted to the National Science Foundation: an Adaptation and Implementation grant proposal and a Department Level Reform grant proposal. He described 10 important facets of the proposal preparation process, such as project goals, preparation time, program solicitation, additional review criteria, and evaluation plan. Jackson's work [16] focused on introducing best practices of proposal writing, rather than on teaching how to write grant proposals. Similarly, Moeller and Christensen [19] and Anderson and Garg [20] described proposal solicitations and how proposals were reviewed at the National Science Foundation [19] and the Army Research Office [20], respectively. Their work [19, 20] did not involve pedagogy, i.e., teaching a class of students how to write proposals.

The only literature that addresses pedagogy is the work done by Mohan et al. [8], who developed a two-semester undergraduate course titled "Preparing Engineering Faculty and Professionals." That two-semester course covered a variety of topics, and only four weeks in the second semester were devoted to developing students' proposal writing skills. The pedagogy they used included: 1) inviting a professional grant writer from their university to deliver a formal presentation, 2) requiring students to study/research a proposal of their choice from a "sample proposals" database, and 3) requiring students to

write a two-page summary for the proposal topic of their choice. In Mohan et al.'s work [8], no mock panels were formed, nor did students write their own proposals. Furthermore, only four weeks were devoted to learning the proposal writing process, which was insufficient for students to gain in-depth proposal-writing experiences. In the present study, students conducted mock panel review and wrote their own proposals throughout a 15-week semester.

1.4 Contents of this paper

First, this paper describes in detail each of the three types of active learning activities: think-pair-share discussions and reflections, mock panel review, and student development of a full proposal. Representative examples from student work are also provided. Next, the paper describes how assessments were performed and provides a summary of the assessment results. Then, two lessons learned from the present study are discussed. The conclusions are made at the end of the paper.

2. Student-Centered Active learning

2.1 Grant writing course

The student-centered active leaning approach was implemented in a graduate course entitled "Finance and Grant Writing." This course, taught by the author of this paper, is a required course in the PhD in Engineering Education program at Utah State University. The course has the following three objectives:

- Develop strong skills and competency to write education grant proposals.
- Critically analyze sample proposals and assess their funding potential.
- Apply what students learned from the course to develop a full grant proposal that targets a specific "Call for Proposal" solicitation from an external funding agency.

The course covers the following 10 major learning topics selected from a textbook [18]:

- Finding public and private finds.
- Pre-proposal contacts.
- Letter proposals.
- Problem statements and project needs.
- Project goals, objectives, and expected measurable outcomes.
- Research method and evaluation.
- Project dissemination.
- Budget design and budget justification.
- Proposal summary and appendix.
- Writing and editing and proposal review processes.

The course was offered to a total of 15 graduate students in two semesters: seven students in Semester 1 and eight students in Semester 2. Throughout the semester, students participated in three types of active learning activities: 1) think-pair-share discussions and reflections on course materials; 2) mock panel review on actual proposals submitted to an external funding agency; and 3) developing a full grant proposal that targets a Call for Proposal solicitation by an external funding agency. All three of these types of activities involved extensive interactions among students, and between students and the instructor. These activities are described in detail in the following sections with representative examples from student work.

2.2 Think-pair-share discussions and reflections

Think-pair-share is an active learning and cooperative learning strategy developed by Frank Lyman and his colleagues in Maryland in 1981 [22]. In the present study, think-pair-share activities are conducted in the following way. During the lecture, the instructor raises a question or asks for comments on a learning topic. Each student *think*s individually first, then *pairs* with another fellow student to *share* their thoughts between each other, and finally report their discussions and reflections to the whole class. Think-pair-share activities not only encourage each student to think, but also promote student-student interactions. During the think-pair-share process, the instructor provides just-in-time instructions and comments on students' discussions and reflections.

An example is provided to illustrate how the think-pair-share process works. In learning how to write a letter proposal (a small-scale letter form proposal), the instructor provided students a sample letter proposal and asked each student to conduct the following tasks:

1. Identify the seven elements of the sample letter proposal. The seven elements are:
   - Summary—a one-sentence proposal overview.
   - Appeal—rationale for approaching the sponsor.
   - Problem—description of need or gap.
   - Solution—method for solving a problem.
   - Capabilities—the project team's credentials to solve the problem.
   - Budget—specific request for funds.
   - Closing—a check-writing nudge to the sponsor.
2. Describe how each element is addressed. For example, is the rationale supported by data and literature review? Is the description of the solution clear, complete, and concise?

3. Describe the strengths and weaknesses of the proposal.
4. Provide suggestions for improving the proposal.
5. Provide a numeral score of the quality of the proposal (10 points for each element, and the remaining 30 points for the overall quality of the proposal).

Each student in the class was required to independently complete all the above tasks. Then, students were divided into several pairs. Each pair exchanged and discussed their answers with each other. After reaching agreement on their answers, each pair reported their answers to the whole class, so all students in the class could share their opinions and learn from each other. An an example, the following are the answers from one pair of students to item 3 regarding the strengths and weaknesses of a letter proposal that the instructor provided to students.

"Strengths: The proposal is organized and clear. Used headings to direct the reader. Used stats for support. State how much funding is requested and how it will be used. The project team has done it before, have experience, and have done their homework on the foundation."

"Weaknesses: The proposal needs more explanation of programs. How do the programs work? How are they going to get the kids and the parents to participate? More clear descriptions are needed on how they are going to market and advertise their services? How can they reach underprivileged? How to get this program to more than just school children likely those with these problems are not in school. The proposal needs to provide an example of the parent/teacher evaluation form."

On how to improve the letter proposal provided, the students recommended that "fix the weaknesses listed above by including more on how the programs work and how they will be advertised to reach the maximum number of students."

2.3 Mock panel review

In order for students to better understand the proposal review process, two mock panels were formed each semester with three to four students on each panel. Efforts were made to ensure the panelists (i.e., students) on each panel had diverse experiences and backgrounds, so they can judge the quality of a proposal from diverse perspectives. Actual proposals submitted to the National Science Foundation (USA) were provided to all panelists in advance. All panelists were required to read the proposal and write down their comments on the proposal before panels met in the class. The two merit review criteria that the National Science Foundation employed were also provided to all panelists. The two merit review criteria are [23]:

Criterion 1: What is the intellectual merit of the proposed activity?

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of prior work.) To what extent does the proposed activity suggest and explore creative and original concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

Criterion 2: What are the broader impacts of the proposed activity?

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

In addition to providing written comments on how the proposal met or did not meet the above criteria, each panelist was required to assign an overall rating for the proposal before the panel met in the class to discuss the proposal. The rating ranged from Excellent, Very Good, Good, Fair, to Poor, which is defined as follows [23].

- Excellent: Outstanding proposal in all respects; deserves highest priority for support.
- Very Good: High quality proposal in nearly all respects; should be supported if at all possible.
- Good: A quality proposal worthy of support.
- Fair: Proposal lacking in one or more critical aspects; key issues need to be addressed.
- Poor: Proposal has serious deficiencies.

During the meeting, panelists listened to each other's comments regarding the strengths and weaknesses of the proposal. After hearing the comments from each other, panelists could change their rating of the proposal. For each panel, a scriber was appointed to write down panel discussions. Based on panel discussions, a panel summary was made along with one of the following three recommendations regarding the proposal: 1) fund, 2) fund if funds are available, or 3) do not fund.

As an example, Table 1 shows two panel summaries on the same grant proposal. The overall goal of

Table 1. Panel summaries by two student panels

	Panel 1	**Panel 2**
Intellectual merit	*Strengths:* The PI and Co-PI are well qualified, based upon grant money received from other programs. The program looks at incorporating rich curriculum and application into the dynamics course. The background information provided is strong. The solution to the problem is good as well as the proposed methods at arriving at the proposed solution. Literature review is strong. More connection between sections is needed. *Weaknesses:* The problem or need was not well defined and not completely connected to the solution. There was no data provided to show the severity and frequency of the problem. The incorporation of physical models as well as computer simulations is neither new nor innovative; how does this differ from other projects? The third objective listed is not addressed in the proposal in that there is no explanation of how or why students will develop the ability to transfer existing knowledge to other engineering areas as a result of this proposal. There was no schedule of when or by whom project tasks will be completed.	*Strengths:* The PI and Co-PIs have substantial funding in engineering education. Their experience and current funding are related to the current proposal. The evaluator has good background as well. The problem, objectives, and outcomes are clear and well tied to the methodology. The cited literature is state-of-the-art. The study uses a previously developed instrument to assess preconceptions. The formatting is easily navigable with headings/subheadings and references within. The graphics were also helpful. The task management is clear. *Weaknesses:* The project management of the software development is not clear. There is no risk mitigation. Also, is the scope of the project too big with their existing grants? Will the interventions work? Is there preliminary data or literature to support what is being done? The problem solving process might be overly simplified; how do we know this will work? The panel is split on the possibility of the project being handled in house. The evaluation techniques have a great potential. However, are these techniques going to receive the rigor necessary for collecting, coding, and analyzing verbal data?
Broader impacts	*Strengths:* This sort of research could provide some very interesting results that could cross many curriculum and course boundaries. The strategy is to solve an old problem or misconception about learning. It not only indentifies the misconceptions, but combines physical models and computer visualization into problem solving. *Weaknesses:* No evaluator named to answer the questions of assessment. Proposal failed to specify criteria for evaluation, including assessment and project evaluation. No dissemination plan was set forth in the proposal. Does not provide an outline of how it will serve the underserved.	*Strengths:* This course module is used by many students throughout the nation. The virtual classroom extends the number of possible students reached. Student learning is at the core of this proposal. *Weaknesses:* There are no dissemination procedures. There is no documentation of a substantial effort to reach out to underrepresented groups, such as rural communities, or another university. The participants are limited to one university.
Recommendation	Do not fund	Fund

the proposed project is to enhance an engineering dynamics course curriculum by bridging the gap between theoretical and mathematical problem-solving and real world application of understanding. Panel 1 had four panelists. Panel 2 had three. Note that Panel 1 did not recommend funding, whilst Panel 2 recommended funding. Panel 2 also reported that "the panel is split on the possibility of the project being handled in house." As well known, all these phenomena often occur in real panel reviews. Therefore, through this mock panel review experience, all students developed a better understanding of how the same proposal could be reviewed by diverse reviewers.

2.4 Student development of a full proposal

Students were required to develop a full proposal of their own to target a specific "Call for Proposal" solicitation from an external funding agency. Because the majority of our students did not have prior experience in writing an education grant proposal before they took the course, the proposal writing process started early in the semester. In the first two weeks, each student was required to generate a proposal idea based on their college learning experiences and based on consultation with the instructor as well. For example, the following are the titles of the proposals that some students decided to work on:

- A real-time instrument for detecting and grading math anxiety.
- High school student systems cognitive processes and strategies in engineering design challenges.
- Adaptive computer-supported learning: enabling engineering design activity in Grade K-12 with personalization approach.
- Improving students' problem-solving in engineering dynamics through interactive web-based simulation and animation modules.
- Offsetting gender bias in STEM fields: Gender equity internet controlled fish farm curriculum activity.

Students started to write each section of the proposal as they learned the course material throughout the semester.

For example, after students learned how to justify project needs in Week 4, students applied what they had learned to complete the "Problem Statements and Project Needs" section of their own proposals. After students learned how to disseminate project results in Week 8, students applied what they had learned to complete the "Project Dissemination" section of their own proposals. Throughout the semester, students also made frequent revisions of their proposal based on the feedback they received from peer students and from the instructor. This revision and polishing process ensured that the final full proposal was of high quality and competitive.

Students were required to submit their full proposal at the end of the semester. The full proposal included all essential elements typically required by an external funding agency. These essential elements are:

- Summary.
- Proposal description.
- Statement of the problem or the need.
- Literature review to support the statement of the problem or the need.
- Goals, objectives, and expected measureable outcomes.
- Methods.
- Evaluation plan.
- Qualification of the PI and the research team.
- Dissemination plan.
- References.
- Budget.
- Budget justification.
- Short 2-page curriculum vitae of the PI and Co-PIs.
- Other appropriate materials that support the proposal.

In addition to submitting a written full proposal, each student orally presented their proposal to the class at the end of the semester. The quality of the written proposals and oral presentations were evaluated by the instructor using a scoring rubric.

3. Assessments and results

3.1 Data collection

Assessment data were collected from a total of 15 graduate students who took the grant writing course from the author of this paper in two semesters: seven students in Semester 1 and eight students in Semester 2. The 15 students included 10 males and five females. A questionnaire survey, which included both Likert-type items and open-ended questions, was developed and administered at the end of each semester. Table 2 shows the assessment instrument employed in the questionnaire survey.

3.2 Assessment results

Figure 1 shows the results of student responses (mean scores) to the Likert-type items on three types of active learning activities described above. The Likert-type items were on a 5-point scale with 1 representing the least effective and 5 representing the most effective. As seen clearly from Fig. 1, the

Table 2. The assessment instrument

Assessment items
1. Did think-pair-share activities help you learn how to write grant proposals? • If yes, describe how they helped you. • If not, describe how they could be changed to improve your learning. • Rate the overall effectiveness of these activities in helping you learn (1: the least effective; 5: the most effective): 1 2 3 4 5
2. Did 'mock panel review' activities help you understand the proposal review process? • If yes, describe how they helped you. • If not, describe how they could be changed to improve your learning. • Rate the overall effectiveness of these activities in helping you learn (1: the least effective; 5: the most effective): 1 2 3 4 5
3. Did 'student development of a full proposal' activities help you learn how to write grant proposals? • If yes, describe how they helped you. • If not, describe how they could be changed to improve your learning. • Rate the overall effectiveness of these activities in helping you learn (1: the least effective; 5: the most effective): 1 2 3 4 5
4. Please describe whether the active learning activities that you have done in this course changed your perception about grant proposal writing.
5. Please provide other comments you have on the active learning activities that you have done in this course.

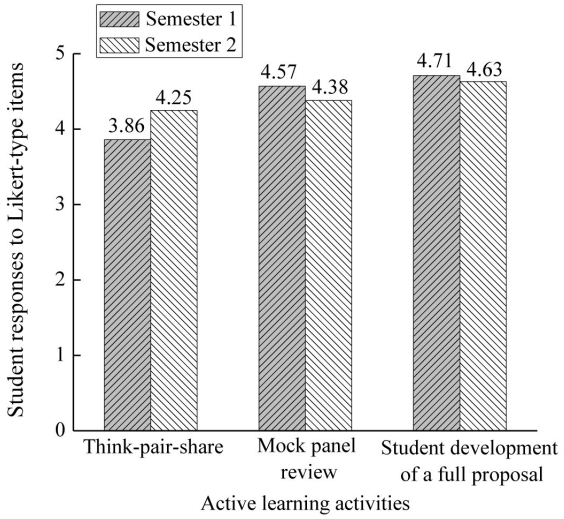

Fig. 1. Student responses (mean scores) to Likert-type items on three types of active learning activities

mean scores of student responses are more than 4.00 for all three types of active learning activities in two semesters, except for think-pair-share activities in Semester 1. Based on what was learned from Semester 1, the instructor added more think-pair-share activities in Semester 2. Therefore, student evaluations on think-pair-share activities on in Semester 2 were higher than those in Semester 1. The high mean scores demonstrate that the active learning activities were effective in helping students learn how to write grant proposals.

Figure 1 also shows that the mean scores on "student development of a full proposal" activities are the two highest mean scores in both semesters: 4.71 in Semester 1 and 4.63 in Semester 2. This suggests that the most effective method for students to learn how to develop grant proposals is learning by doing, i.e., each student develops a proposal of his/her own.

In student responses to open-ended items in the questionnaire survey, all students expressed that the three types of active learning activities helped them learn grant proposal writing. Representative student responses [original, without editing] are listed in the following paragraphs:

Regarding think-pair-share activities:

- "Getting another's opinion and paring to work does two things for me. First, it forces me to think because I have to articulate my ides. Second, I get to see how others view things."
- "It made me verbalize and explain my thoughts. Verbalizing helped me to learn."
- "They helped me learn because I have another perspective especially when we are discussing examples of proposals and our own proposals."
- "Discussing examples with others helped me to better understand the material and prepare a better proposal of my own."
- "Think about things that I did not see or realize."

Regarding "mock panel review" activities:

- "I enjoyed seeing the give and take of the proposal review process—it was fascinating to watch opinions change as people made their arguments."
- "They helped me synthesize all of the ides and see how proposals are viewed by others after some serious review."
- "Better understanding of the review process helped me write better. It had helped me to see some of the weakness others might see in my own proposal."
- "Seeing a full grant proposal was a big help. Getting others' opinions of proposal helped me to write a better proposal."
- "They were helpful because we shared our views on the strengths and weaknesses of different proposals. I changed some segments of my own proposal after these activities."
- "It is good to get to know what others think, and get their feedback, suggestions, and improvements."
- "The panel review was fantastic! I was finally able to "think" like a reviewer."

Regarding "student development of a full proposal" activities:

- "There is no way to learn this without doing it."
- "The only way that I can learn how to write a proposal is just "writing a proposal". I think this was the most valuable part of the course."
- "Nothing like doing to help you learn."
- "Getting feedback on my current proposal helped me write better proposals in the future."

In addition, students also expressed the changes in their perceptions on proposal writing before and after taking the course. For example, students expressed that:

- "Initially I did not think there was so much review of literature and more simply identifying the problem."
- "Before taking the course, I never noticed that a proposal should contain essential sections such as project evaluation and dissemination."
- "There is a lot more work and pre-writing research that needs to be done before a proposal is written."

4. Lessons learned and discussions

The assessment results described above prove that active learning, in which students are engaged in the

learning process [24–27], is effective in improving student learning outcomes. The following two lessons were learned from the present study.

First, the earlier students finalize their own proposal ideas within the first two weeks of the semester, the better off students would be in developing high quality proposals. As competition for funding becomes increasingly fierce, the proposal idea becomes increasingly important in determining whether the proposal would be funded or not. Nearly all other elements of a proposal (such as the justification of the needs of the proposed project, research methods, and evaluation) are developed and organized based on the proposal idea. For example, if one chooses a proposal idea that has little intellectual merit and minimum impact in the education community, the proposal would have less or no chance to get funded. However, the vast majority of the engineering students who took the author's grant writing course had no prior experiences in writing educational grant proposals. At the beginning of the semester, some students encountered challenges in determining a particular idea for their own proposals. One student in the class even changed his proposal idea three times in a week. One possible method to solve this problem is to have students think of and study a research topic prior to starting the course. For example, three or four weeks before the course starts, the instructor holds an orientation session to the students who will take the course, and encourages all students to think of and study a research topic that they deem important. The instructor can also send students relevant course materials for them to read in advance, so students are well prepared when they enter the class.

Second, more time should be allocated to discuss students' own proposals. The assessment results described in Section 3 of this paper have shown that requiring students to develop their own proposals is the the most effective method for students to learn how to develop grant proposals. In general, the more discussions and revisions on a proposal, the better quality the proposal. However, restricted class time did not allow for sufficient and in-depth discussions and reviews of each student's own proposal. One student suggested making this one-semester course a two-semester course. Unfortunately, this suggestion is not practical due to the curricular design of our PhD in Engineering Education program. A possible solution is to encourage each student to discuss their proposals outside the classroom. The instructor also holds more office hours to provide students just-in-time feedback and advice on students' proposals.

Finally, it should be pointed out that the number of students participated in the present study was limited. Because our PhD in Engineering Education program was established only recently, there were only 15 graduate students involved in the present study. The statistical analysis would be enhanced if the sample size could be increased.

5. Conclusions

Grant proposal writing plays a significant role in tenure and promotions of faculty members as well as curriculum reforms and laboratory improvements. It is also a strong indication of a person's communication skills. As many engineering students lack essential training and education on how to develop competitive grant proposals, a student-centered active learning approach to teaching grant proposal writing has been developed in the present study. This approach combines three types of active learning activities: think-pair-share discussions and reflections, mock panel review, and student development of a full proposal of his/her own. The approach has been implemented and assessed in a grant proposal writing course in a PhD in Engineering Education program at the author's institution.

Questionnaire surveys have been administered in two semesters to assess the effectiveness of this approach. The results show that, on a 5-point Likert-type scale with 1 representing the least effective and 5 representing the most effective, the mean scores of student responses are more than 4.00 for all three types of active learning activities. The mean scores on "student development of a full proposal" activities are the two highest mean scores in both semesters: 4.71 in Semester 1 and 4.63 in Semester 2. This implies that the most effective method for students to learn how to develop grant proposals is learning by doing, i.e., each student develops a proposal of his/her own.

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