# 2006-1122: LEARNING JOURNALS AS A CORNERSTONE FOR EFFECTIVE EXPERIENTIAL LEARNING IN UNDERGRADUATE ENGINEERING DESIGN COURSES

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# Learning Journals as a Cornerstone for Effective Experiential Learning in Undergraduate Engineering Design Courses

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## Abstract

Learning journals are implemented in undergraduate engineering design courses to encourage students to reflect actively on what they can learn from their personal experiences with team projects, lectures, and assignments. These journals are intended to catalyze student reflection and thus enhance student understanding, retention, and capacity for future application of course content. An invaluable side-effect of the journals is continuous feedback that enables real-time adjustments to course schedule and pedagogy. Implementation details are reported in this paper, including sample reflective prompts, grading rubrics, and sample journal entries with the corresponding instructor feedback provided. Results of student opinion surveys are also discussed. As described in this paper, our experiences and observations throughout the semester-long course motivate us to continue implementing refined versions of this pedagogical tool in design courses.

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## 1. Introduction

Design projects and activities are crucial ingredients in graduate and undergraduate engineering design education for providing concrete experiences. Such experiences are fundamental components in Kolb's model of experiential learning.[1] Experience alone, however, is not helpful for students unless they *learn* something in the process, as noted in Dixon's survey of engineering education.[2] Accordingly, we have instituted *learning journals* in undergraduate engineering design courses to encourage students to *reflect on what they can learn from their personal experiences* with design projects, lectures, and assignments. The learning process involves metacognition (the monitoring of one's own learning) and while this is a natural process, it often needs reinforcement and improvement through practice.[3] As reflective activities, learning journals are intended to help students enhance their own learning processes.

Our learning journal initiative is predicated on two primary assumptions: (1) one of the most effective ways to encourage lifelong learning among engineers is to encourage them to be reflective about their professional and educational experiences and to apply those insights to future activities,[4] and (2) learning journals catalyze critical thinking and reflection as students articulate and generalize the lessons they have learned.[5-8] Journals are also cited as effective tools for enhancing student creativity[9] and active (versus passive) forms of learning.[5] In addition to promoting reflective learning, learning journals are excellent feedback mechanisms for instructors to evaluate student design processes[10] and monitor student comprehension of and receptivity to specific course topics, along with general feedback about the course.

With enhanced student learning in mind, we have introduced semester-long learning journal assignments into undergraduate mechanical engineering design courses. The instructor guides the journaling activity by providing reflection questions to aid in topic selection, along with exemplary samples and a grading rubric to establish expectations. In turn, the students are required to write short weekly journal entries of 200-500 words that culminate in a 1000-2000 word final entry at the end of the semester. In this paper, we provide an overview of the learning journal initiative and a critical analysis of its inaugural semester, based on instructor perceptions, course evaluations, exit interviews, and student surveys. Our positive experiences and observations motivate us to continue implementing and refining learning journals as a pedagogical tool in engineering design courses.

In the next section, we provide an overview of the learning journal initiative, including assignment details, sample reflection questions that prompt deeper thinking and reflective writing, and a rubric for evaluating the journals. In Sections 3 and 4, we include annotated student entries and a summary of student feedback on learning journal effectiveness. In Section 5, we summarize the lessons learned from the authors' experiences and provide suggestions for implementing learning journals in engineering design courses.

## 2. An Overview of the Learning Journal Initiative

The learning journal initiative at the University of Texas at Austin is integrated into an established mechanical engineering design course for senior-level undergraduates. In teams of four or five, the students reverse engineer and redesign a mechanical, electro-mechanical, or

thermo-mechanical consumer product of moderate complexity. Through classroom lectures, activities, and readings, the students are introduced to systematic design methods for negotiating solutions to open-ended engineering design problems. The intensive semester-long team project provides an opportunity for students to practice their design skills by reverse engineering and re-designing a complex mechanical artifact. The project also provides concrete experiences that form the basis for personalized observations and lessons learned about the design process. The entire course is designed to encourage students to develop a deeper understanding of the design process and a mental framework for design that can be applied to future projects, including an industry-sponsored capstone design project in the following semester.

In this context, the learning journal provides an opportunity for students to record their observations, reflections, and lessons learned from class lectures and activities, projects, and independent study. As part of the semester-long learning journal assignment, students are required to make weekly entries of 200-500 words. In their weekly entries, students may write about any topic of relevance to the course, but they are encouraged to describe lessons learned from projects and in-class activities. To help the students focus and structure their entries, we pose a set of *reflection questions* at the beginning of the course and at the end of each lecture. The reflection questions encourage students to evaluate their project-based experiences and to think deeply about the concepts presented in class; including the strengths, limitations, and potential breadth of applicability of course content and activities. Also, students are encouraged

**In-Class Activities**

1. Think about your team tower-building exercise (an in-class activity on the first day of class).
   - Describe your design and manufacturing process.
   - What went well? Why? How could you build upon it in the future?
   - What difficulties did you have? Why? How could you improve in the future?
2. Last week, you used an ad-hoc technique to generate concepts for a golf-ball retriever. Today, you used a systematic method. Compare the breadth, quality, and number of concepts from the two trials. How would you explain the differences?

**Lecture Topics**

3. Do highly innovative products typically serve new functions? Or do they satisfy old (previously satisfied) functions in new forms?
4. In what situations during your career do you expect reverse engineering techniques to be useful? Not useful? (Explain why.)
5. Identify some mistakes that could lead to poor results in a concept selection process.
6. How would you archive your work in embodiment design so that other designers could understand it, re-use it, and leverage it for redesign or adaptive design?

**Projects**

7. Tell us about something you learned or found interesting in your project work. Why is it interesting? What did you learn?
8. Tell us about something that went well/badly in your project work. Why? How can you build upon it or overcome it in the future?
9. How would you apply 'design of experiments' techniques to your project? To other projects you've encountered?
10. Is your product part of a family of products? As a designer, how would you offer customized versions of the product efficiently?

Figure 1. Sample reflection questions to prompt learning journal entries.

to draw parallels from their professional and personal experiences and to hypothesize potential applications of the course material. Sample reflection questions are included in Figure 1 for illustration.

The learning journal assignment culminates in a 1000-2000 word final entry in which each student describes the three most important concepts learned in the course and how those concepts will be useful in his/her future profession.

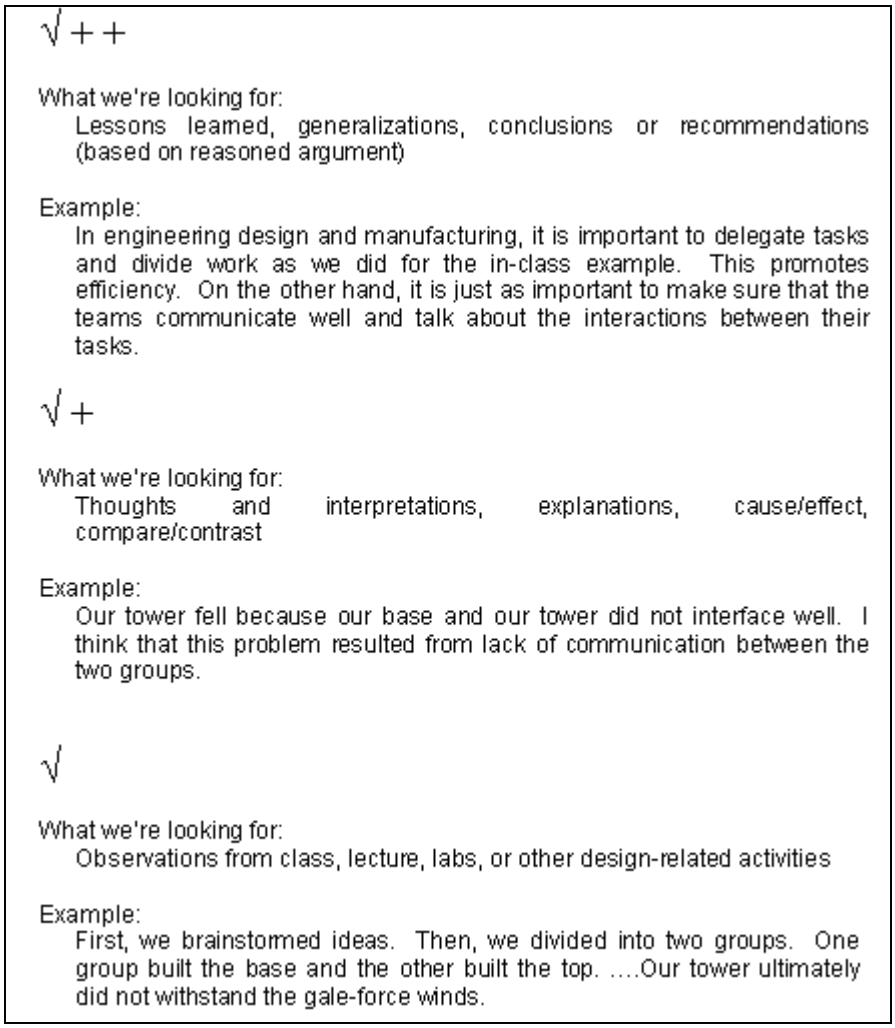


Figure 2. A rubric for evaluating learning journal entries.

A rubric is used for establishing consistent grading standards and communicating our expectations to the students. As shown in Figure 2, the rubric is based loosely on Bloom's taxonomy.[11] This taxonomy, developed in 1956, has evolved into a classic work that classifies cognitive behaviors into six categories ranging from simple to complex. To receive credit for the entry (√), students are expected to be able to recall and describe their experiences from class activities, project work, or other relevant activities. These entries correspond to the "knowledge" level of Bloom's taxonomy. To receive additional credit (√+), students must interpret or explain

their experiences, at the "comprehension", "application", and "analysis" levels of Bloom's taxonomy. To receive maximum credit (√++), students must evaluate their experiences, at the highest level of Bloom's taxonomy, and include reasoned arguments that support lessons or recommendations for future design activities. The *qualitative* nature of the grading system—based on check marks—is intended as a medium for providing feedback to students while focusing them on learning and thinking rather than on grade-driven completion of tasks. Eventually, the marks are converted to numerical grades. Check (√) to √++ corresponds to 85% to 95% credit, with lower grades for missing or unacceptable essays and higher grades (100%) for students with exceptional performance throughout their entries.

## 3. Discussion of the Learning Journals

Students write a total of 10 entries plus a final entry during the course of the semester. Journals are collected and evaluated every 3-4 weeks throughout the semester, and the final entry is evaluated at the end of the semester.

When we first implemented the learning journals, the quality of the entries improved noticeably throughout the semester. The improvement was correlated with our efforts to communicate expectations more clearly to the students. When we collected the first set of entries at the end of the third week of class, most of the essays fell towards the lower end of the rubric in Figure 2. Many students treated the journals as diaries in which to record descriptions of daily events in class or in their project work. In general, most students included only superficial thoughts or reflections on those activities and neglected to extract any explicit lessons or conclusions.

Even low-level descriptions of course content are likely to enhance retention of course material, but our goal was to encourage deeper understanding and internalization of the design process. To improve the depth of the entries, we developed a three-pronged strategy. First, we provided hand-written feedback on each entry. We highlighted specific points, provided positive feedback for interesting thoughts and conclusions, and challenged the students with interesting questions or counterpoints relevant to their entries. Sample excerpts from a few entries with instructor feedback are provided in the appendix. Second, we provided specific examples of outstanding or "best practices" entries and reviewed them in class, highlighting the passages that demonstrated depth of thought and learning. Third, we developed the rubric illustrated in Figure 2 and shared it with the class.

After we implemented this three-pronged strategy, the quality of the entries significantly improved. The average journal grade increased one full level in the rubric from the beginning to the end of the semester, even though our grading standards became more demanding. The students began to do more than just describe course-related events in their entries; they also began to extract meaning from them and form their own conclusions. As illustrated in the sample entries in the appendix, student entries generally fell into one of four categories (Table 1), motivated partially by the types of reflection questions posed in class. (1) In most cases, students directly answered reflection questions which required them to think about the application of course topics to product design scenarios or to explore the strengths and limitations of specific design methods. (2) In other cases, students wrote about hands-on, in-class activities and resulting changes in their perspective on the design process. (3) In a third

type of entry, students related course topics to their own industrial experiences or to their future career plans and identified which topics would be most useful to them and why. (4) In a fourth category, students discussed their projects, either to make connections with course topics or to discuss teamwork and leadership styles.

**Table 1. Four categories of journal entries received.**

| |
|---|
| 1) Direct answers to reflection questions – applying course topics to product design scenarios. |
| 2) Recounting in-class activities and resulting changes in design perspective. |
| 3) Relationship (and relevance) of course topics to industry experience or career plans. |
| 4) Relationship of reverse engineering projects to course topics. |

Regardless of the topics, the journals were valuable sources of feedback for the instructors. If portions of our lectures were particularly effective, we would find the associated concepts repeated in multiple journal entries. If we did not motivate a concept effectively, students would criticize it harshly and in an unbalanced manner. Students often openly mentioned aspects of the lectures, assignments, or teaching style that they particularly liked or disliked. Because the journals are evaluated periodically throughout the semester, this feedback is obtained early enough to modify the course to suit the students' learning styles and backgrounds.

## 4. Survey of Student Opinion on Learning Journals

Based on our reviews of the learning journals throughout the semester, we are confident that students benefited from the activity in terms of deeper understanding and better retention of the course material. An additional objective of the activity is to encourage students to view writing as a valuable tool for any professional engineer—not only as a form of documentation but also as a means to think through a design problem and understand it more clearly. We want the students to enjoy professional writing—or at least to appreciate its value—so that they are more likely to continue the practice in the future as a form of lifelong learning.

1. As an engineer, I find writing …
   Painful Tolerable Enjoyable
2. Before ME 366J, were you required to keep a journal for any class at UT?
   Yes No
3. In ME 366J, I found the learning journal requirements to be:
   Useless Somewhat Useful Useful
4. How did the learning journals help you think about the course?
5. As a result of your experiences in ME 366J, would you be more likely to incorporate journals in your professional work habits?
   Yes No Maybe
   Please explain your answer.

Figure 3. Assessment survey questions.

Accordingly, we conducted an anonymous survey of student opinion on the learning journals. The purpose of the survey was to gather student feedback for iterative course improvement. We polled the students six months after completing the course by distributing the surveys during a meeting of their subsequent capstone design course. We received responses from 47 students or 55% of the original class. (The rest of the students either graduated during an intermediate summer session or delayed their capstone design course until a subsequent semester.) In the survey, we asked a series of writing- and journal-related questions as shown in Figure 3. We also requested basic demographic data such as GPA, expected graduation date, number of semesters in a professional internship, and future career plans, so that this data could be correlated with responses to the writing-related questions. We wanted to explore whether particular attributes, such as GPA, influence student perceptions of a task like writing.

More than 54% of students found writing tolerable and 37% found it enjoyable; less than 10% found it painful. Although only 13% of students had been asked to keep any type of journal before they enrolled in our class, 20% of the students replied that they *would* be more likely to keep journals as part of their professional work habits, and another 43% replied that they *might* be more likely. Many of the students recognized journals as a means for documenting their findings, thoughts, and general progress over the course of an engineering project. Some students noted that a journal would help them keep their thoughts organized and place their work in a larger context. In their explanations, some students distinguished between *design* journals and *learning* journals. Some students noted that they would be more likely to keep *design journals* in which they record calculations and notes, especially for legal or invention purposes in an industrial setting. A few students commented that they would only keep journals if they were *required* to do so.

More than half of the students (53%) found the learning journals to be at least somewhat useful to them. Students who found the journals useless generally remarked that they found them tedious or burdensome or considered them busy work to be completed just before class. Interestingly, students with higher GPAs tended to rate the journals as less useful. A possible explanation—based partially on previous experience in engineering education surveys and research by one of the authors—is that students with very high GPAs were uncomfortable with the ambiguity of the assignment and the evaluation criteria. Combined with their desire to earn an A in the course, this impression may have catalyzed a general feeling of negativity among those students. Students who found the journals useful or somewhat useful generally remarked that the journals helped them learn specific concepts more thoroughly, communicate their thoughts to the professor, and keep their thoughts organized in a fast-paced course. They also remarked that the journals provided an opportunity to review lectures and other experiences, think about the concepts, and understand them better by writing them in their own words and opinions. One student remarked that "*it forced me to formulate my thoughts into words and actually find a lesson in my work*."

The student opinion survey raised awareness that many engineering students do not *naturally* enjoy reflective writing and that this factor must be taken into account when implementing similar initiatives. Efforts by the instructor to reinforce the value of the writing assignment may be crucial to its success.

## 5. Ongoing Refinement of the Learning Journals

We plan to continue using journals as a pedagogical tool in undergraduate engineering design courses. Our preliminary observations and insights are based on an initial, semester-long implementation of learning journals in an undergraduate engineering design course. Those conjectural insights suggest that journals are an effective means for encouraging students to reflect upon course topics and retain the material more effectively. Furthermore, our practical experiences suggest that journaling helps students gain a deeper understanding of design methods and how to apply them to potential technical challenges. The journals also encourage students to extract concrete lessons from their design experiences and archive those lessons for future applications. Finally, the journals are a valuable source of ongoing feedback on the effectiveness of pedagogical strategies and the general pulse of the class.

We have identified several opportunities for refining our use of learning journals. We are working to guide the assignment more effectively to reduce anxiety among students who are unfamiliar with such an assignment and eager to earn high grades. At the beginning of the semester, we are providing simpler and clearer instructions for students, examples of good journal entries, and a rubric to explain our grading system. To reach students with a broad range of capabilities, we are incorporating reflection questions that target various levels of Bloom's taxonomy—not just the highest level—by asking students to apply a course topic to a familiar design or product, for example. We are also working to avoid any initial impressions of the journals as experimental or childish because we believe that students are much more likely to continue the practice of journaling if they perceive it as an important part of professional activities. Accordingly, we are changing the official name of the assignment from 'learning journals' to 'design notebooks,' and merging it with project notebooks in which students record daily project activities. We also emphasize the journal as an important archive for their newly acquired design skills and knowledge—an archive that will be useful to them in future professional activities. As we implement many of these refinements in current courses, we are optimistic that learning journals will become an indispensable tool for educating the reflective engineers of tomorrow.

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## Appendix

The following passages are excerpts from student learning journals. Student text is in italics.

(1) In the following excerpt, the student responds to a reflection question, "Is there always a one-to-one correspondence between functions and components?"

> "*…. There is not always a one-to-one correspondence between sub-functions and components. Depending on what a manufacturer aims for with his product (low cost, flexibility), he can take an integrative or modular approach. Integrating many functions and sub-functions into one part may eliminate assembly time, reduce equipment cost, and reduce defects. This seems desirable in general, but it obviously will not work for all products. A car, for example, should ideally be modular so that the same parts can be used on multiple models. Nissan uses the same base for both its 350Z sports car and its higher-end Infinity equivalent. Modularity allows mass customization but increases assembly complexities, while integration does not. But both approaches can create winning products when applied properly.*" [Instructor Feedback: Powerful insight! If you're interested in this topic, you might like to glance at a book called *The Power of Product Platforms* by Meyer and Lehnerd. It's the story of how Black and Decker revolutionized its product line around standard components and interfaces.]

(2) In the following excerpt, the student presents lessons learned from an in-class activity involving concept generation for a golf ball retriever:

> "*…. The first thing my group did was brainstorm some ideas. Since we had to consider the stipulations (i.e., cost and performance), the ideas came rather slowly…. Each group member was thinking really hard how to come up with an idea that met all the requirements. In fact, several group members shot down other people's ideas because they did not meet all the requirements. It's hard to tell if this is a good thing or a bad thing… I would have to say it was a bad thing because it's possible that those shot-down ideas could have been revisited and revamped to work within the stipulations…. From this, I understand that after generating some ideas, go back and remove the stipulations. Then brainstorm some more. We were surprised to see how different, yet manageable, our new ideas were*." [Instructor Feedback: Good Point! Excellent!]

(3) In the following excerpt, the student evaluates two lecture topics (optimization and experimentation) and relates them to her expected career field:

> *"…Experimentation is another very useful technique I learned this semester. It is a great way to uncover design interactions. One short-coming to using just optimization in the parametric design stage is that an inaccurate analytical model may make the optimal choice impossible to implement. If there is a large schism between experimental results and analytical predictions, there could be incorrect physical interpretation or faulty assumptions. Depending on the situation, the optimal design configuration may be difficult to prototype or manufacture. Employing an experimental based evaluation provides valuable data about actual different combinations…. Experimentation is yet another tool that may be used to fully evaluate a complicated problem. (However) in my field, it is very difficult to rely on actual experimental data since it is impractical or impossible to conduct the experiment on a full size (nuclear) reactor…."* [Instructor feedback: Great Point! Excellent!]

(4) In the following excerpt, the student recommends teamwork strategies based on his own team-based project experiences:

> *"Balancing team dynamics is very important to having an effective team…. It is very important to give and get feedback throughout the project. Also it is very helpful to give recognition and praise for work that is done. Giving constructive criticism while being respectful is crucial as well. Furthermore, maintaining a professional attitude and knowing that disagreements about the project are not attacks on the individual can improve the effectiveness of the team."* [Instructor feedback: I agree! I like your outlook here!]