Sequential Development of Writing Skills

Richard Hale, Aerospace Engineering

Aerospace Engineering (AE) students use writing in a three-course sequence to develop critical thinking, reflective design, analysis, and communication skills.

OVERVIEW

<u>Background</u>
Articulating thinking through writing

AE sophomore and junior students take a three-course sequence studying Design, Analysis, and Manufacturing. When I first began teaching these courses, I had just arrived at KU from a position in industry. I knew students needed more than just techniques to be successful in their careers, and I decided that incorporating writing across the sequence would be the best means to help them gain a deep understanding of the material. Through writing they could develop critical thinking, reflective design, analysis, and communication skills.

The students use a variety of writing projects in these courses. Some are individual, some are group, some are short reports, others are on-line presentations, and some are cumulative across a semester. The students write for different audiences; for instance, a group of engineers would expect a passive style heavy on technical details while consumers would expect an active voice that is less detailed and provides more reasons for choices. I believe that the writing forces students to make decisions, explain those decisions, and communicate their decisions in an appropriate manner. The learning becomes deeper when they have to articulate their thinking through writing.

<u>Implementation</u>
How I approached the project

One central project—an Antarctic remote sensing device that measures the effects of global warming on the polar ice cap—provides the scenario for the student work across the three courses. In each course, I define the basics and the students fill in the details based on the system that they are currently studying.

The students explain their work through a variety of writing projects. In AE 421, they write both a one-page marketing paper and create a design group report that often exceeds 100 pages. The AE 508 paper is a group technical report. The students use a virtual medium in AE 510 to create a presentation. By varying the type of project, I provide students with an opportunity to analyze, communicate, and defend their decision-making process.

<u>Observations</u>
Broader and deeper understanding

The work that AE students do in my three-course sequence reassures me of the benefits that come from this writing-intensive work. These sophomore and junior students do work that goes beyond what is usually expected at this level. By writing about their decisions, they have to demonstrate understanding that does not show up were they to only answer sample equations, the work product typically required from similar courses.

This broader and deeper understanding of the material also shows up when our students enter and win national design competitions. These competitions are judged by professionals, not academics, and professionals look for projects that show a solid design plan, implementation, and explanation. Because our students have to document and explain their decisions throughout course projects, they are well prepared to use professional judgment in their creations.

Reflections
Some reflections

The written projects that students do in this three-course sequence requires a lot of work from me, but I have found the challenges are interesting, not overwhelming. Both the students and I are enthusiastic about the work. The good results that have come from these projects have convinced me that our department needs more writing across our curriculum.

In order to do curriculum reforms, we will consider a couple of ways of integrating teaching and research. We need to work together on teaching across courses so that we use writing and make connections beyond the three-course sequence. We have already decided to extend the writing to two other courses, and that means we will have to plan together how we implement the work. The research that we are doing can also be connected to course work; this will provide more realistic integration of the academic and the professional world. Because we are part of a university, we can also connect disciplines that are part of the larger professional practice and thus give students an even more realistic education.

BACKGROUND

Technical abilities alone are not enough to make young engineers successful in industry. They need to be able to communicate about their projects to diverse audiences who will include technical peers and non-technical reviewers.

The curriculum-wide emphasis on writing begins in the AE Freshman Seminar. In it, students are expected to write short reports summarizing emerging technologies or current events related to engineering ethics. In addition, numerous technical reports, both individual and team, are assigned since this is a style of writing not often presented in high school. Finally, students are encouraged to develop resumes and five- and ten-year goals.

I teach a three-course sequence: AE 421 (Design) and AE 508 (Analysis) are taken in the spring semester, and AE 510 (Manufacturing) is taken the following fall semester. Each course offers one of three different vantage points regarding the same AE project: Design looks at what can be done from a "clean sheet," Analysis allows students to make detail performance calculations on that design, and Manufacturing addresses the issues involved in producing it efficiently.

Project Notes

Goals
    The project that the students work on across the three classes is an Antarctic remote sensing device that measures the effects of global warming on the polar ice cap. I define the basics, and the students fill in the details. They can move or change different components, such as the wings, tail, or engine. Again, though, there is a price to pay for each change, and by writing about that change, the students are required to detail why they made that decision

- Students will use writing to make explicit connections between curriculums.
- Students will learn how to handle engineering ideas verbally.
- Writing will allow students to reflect on their choices.
- These projects will provide students with an opportunity to listen to "experts"—and then decide what is the best way to proceed on their project.
- Students will be able to synthesis material in order to tell a story about their project and why they made the choices they have. Also, they'll be able to articulate why their choices are better than those made by other student groups.

Why writing?
    Writing forces students to think about their decision process. If the students don't have to write down what they're doing, they don't "unload" their reasoning process. The decision process is the most important part of designing. Students need to be able to answer "Why? Who does it affect?" regarding their designs. The reports for AE 421 are about 100 pages long. The students have done lots of creative work in their projects and the report forces them to explain their decisions. Again, every choice that they have made affects a lot of people. For instance, if they make a change on the wing, this will affect those concerned with propulsion, etc.
    The text documents that they remember and understand material that they have discussed with the instructor. During the creation, the students have to come to the instructor and orally justify the changes that they are making.
    Writing makes students document their decisions. I give them purposefully conflicting information during the design stage. I represent different documents, and the students have to take that conflicting information, make a decision, and then justify why it's important that they make this choice instead of a different one. In their written reports, it becomes obvious if they have thoroughly considered the different aspects or not. By doing so, it's also easier for the teacher to find and correct any errors that they have made. This, I believe, is important for young engineers.
    Communication is huge in industry. Engineers have to be able to communicate about all aspects of their projects with their fellow workers. I came to KU right out of the AE industry. Therefore, I run my classes with an industry framework in my head: I tend to emphasis the practical more than the theoretical. Thus, the students have to be prepared to write reports that can be shared with many groups.

Writing allows for reflection. If students don't write it down, they don't think. In the sister class, AE 508 which is taken simultaneously with AE 421, the students study the analysis of the design. In this class, they have to answer why they did the design—why did they choose this or recommend that change. So, again, their written report makes them unload the ideas that they are carrying around in their heads about the design changes.

Students are analyzing work other than their own early on. The projects in AE 421 are group projects. Each student is in charge of a particular segment of the report. They write separately and then read and peer edit each other's work. This makes them stop and think about the overall design of the project. More than one part is important, and reading what others are doing makes them see the interconnectedness of the various subdivisions in the work. The students have become used to this idea, and usually come up with a format at the beginning of the project. By doing so, they not only save time, but they are figuring out how to make their particular section analogous to the rest from the start.

A written document, with comments from the professor, provides a useful means of increasing the learning benefits from the previous semester's work. Having a sequence of courses allows writing continuity from semester to semester. The students receive their graded reports at the beginning of the next course. At that time, they look at each other's work. They perceive the strengths and weaknesses of the other designs, and from that decide how they will adapt their ongoing projects. Not only does the review serve as a review of what they have learned after the semester break, but also it continues the analysis process begun earlier when they have to decide what ideas will be used and which discarded. By looking at the same design over three classes, the students consider the different vantage points of instruction (design, analysis, and manufacturing) as well as continuously working on their writing skills.

Course syllabi
    See files for course syllabi.

IMPLEMENTATION

AE 421 students have to create an entrepreneurial enterprise marketing paper. This one-page paper helps students to look at their idea from the consumer's point of view, and it requires that they write concisely. The final delivered product for AE 421 is a uniform group report describing the design of an engineering product and explaining why their design is superior to their peers. Generally, this report is well over 100 pages. Each student works on a segment of the report that must be coordinated into a cohesive single report.

The final delivered product for AE 508 is a group technical report identifying the detailed analyses for an engineering product. Again, this report is generally well in excess of 100 pages. Here, the importance is to demonstrate that an effective and accurate analysis is only as good as the presentation and that no engineering analysis is static.

In AE 510, in addition to a cumulative semester project, the students complete a mid-semester design report or presentation using a virtual medium. The writing for this needs to be precise, consider audience, and use a format that will be widespread in industry.

Project Notes

Department support
　　The AE department has supported and continues to support writing. They consulted with the KU Writing Center initially in order to get ideas about student writing. When I was hired, I began using writing projects in the three-course sequence with this in mind: to make connections between the courses and to use writing to emphasize those links.
　　Our department also emphasizes that AE students work on different types of written reports. The students are taught to consider their audience and to adopt a voice that is appropriate for each. The technical reports that engineers write often use the passive voice. However, proposals may go to non-engineers and as such are more appropriately written using the active voice. For instance, if an engineer uses too much of an optimistic, salesmanship voice (active) that is short on precise details when speaking to fellow engineers, they will rip the presenter apart. And conversely, if a group of non-engineers listens to a report written with a dry, passive voice, they rip the presenter apart.

OBSERVATIONS

- The AE students from KU win extracurricular design projects each year. Those good results come from the documentation and communication required across the curriculum in their written work.

- Students graduate able to write different types of reports suited to their audience.

- All AE graduates from all colleges have technical skills; the KU AE students' ability to communicate their skills distinguishes their work. The course writing that students do is as close to experiential learning as they can get. They do the work plan, document their changes, and build the design.

- Anyone can have a student run a sample equation—but it's hard to see if they really understand the material or if they just came up with the correct answer. Writing gives students a chance to apply and demonstrate comprehension. It's a higher level of understanding than solving an equation.

- I am impressed with the level of competency in reports, especially considering these are sophomore and junior students. They are making important connections.

Project Notes

AE 421 student work
AE 421: Aerospace Computer Graphics (Design)

This is the work of early students, and typically such courses would focus on the geometry computer program. However, these students are weighing five or more requirements and using the geometry component to create an engine. The general expectation is that they would be modeling the geology of an engine. Also, they have to give reasons to redo the engine. This means that they are functioning as professionals. They are making decisions, giving me the reasons for their decisions, and I find that these are good decisions and reasons.

Check supplemental files for this information:
- Project assignment from AE 421
- Sample of AE 421 students' work on this project
- Prof. Hale's review of the students' project

AE 508 student work
AE 508: Aerospace Structures II (Analysis)
Check supplemental files for this information:
- Project assignment from AE 508
- Sample of AE 508 students' work on this project
- Prof. Hale's review of the students' project

AE 510 student work
AE 510: Aerospace Materials and Processes (Manufacturing)
Check supplemental files for this information:
- Project assignment from AE 510
- Sample of AE 510 students' work on this project: overview and report excerpt
- Prof. Hale's review of the students' project

Student awards
In 2003, the KU AE students won the first overall in all categories for the Society of Aerospace Engineers competition for students. They had to design, build, and fly a heavy-lift aircraft. This process, moving from paper to flight, is a significant award and more important than winning for a paper design.

In 2004, they won fourth overall while taking firsts in best overall design and best design report. (To see a copy of the report, see "KU SAE Report".) This indicates that they can document their judgment better than their peers and that they can use professional judgment. I think it's important because the judges are professional Aerospace Engineers, not academic AEs, which indicates a demonstration of their professionalism. We are trying to make professional results more representative of the KU AE students instead of academic results, and when students place high in the eyes of professionals, that indicates we are succeeding.

REFLECTIONS

Doing this writing doesn't make my job easier, but it makes it a lot more fun. It's easier to come up with a cut and dried project that has one answer. However, the students get enthused and push me hard, which makes it worth the work. We need to do more, for this isn't enough. We need to get writing into all classes, to increase it, not decrease it.

One stumbling block is that more writing will require team teaching. There will be a value in working together to connect ideas from class to class. We need to think about how to frame curriculum reform to make connections outside a discipline. The first level is the disciplines in AE: structure, propulsions, etc. But, we'll need better connections in our department and across other fields such as electronics, environment, and legal. A campus is the ideal place to do this.

Another step is to put together teaching and research in order to do more realistic projects. This will expand the connections students can make, and this will support ongoing departmental research.

Right now we're trying to find external projects that would require delivery to a customer so our students' work is closer to real professional practice. I am currently working with the KU entrepreneurship alliance on campus. This group will help us get together with other campus entities, such as legal specialists, who can interact on our student projects.

Project Notes

Curriculum reform
    The AE department is considering curriculum changes based on the success of writing in AE classes. While many classes already do utilize writing, we continue to explore ways to improve the experience of our students. One way to do this is to expand the writing further so that it connects even more courses and branches out to connect faculty research projects to these courses. Here are my notes on the proposed philosophy behind AE curriculum reform:
    KUAE faculty collaborate closely to enable practical, experiential learning on projects of global significance. The curriculum improves student learning through meaningful connections between disciplinary subjects, enabled through an immense philosophy of design, build, test, and fly. Projects span courses, such that a student may experience maturing a concept and examining a problem from multiple disciplinary vantage points. Curriculum initiatives are sustained by strategic alignment of goals for teaching and research.

Department engagement
    These classes are part of a system of systems. Each class that the students take represents a system, but that's not the way the world works. Instead of implicit connections, I want students to make explicit connections, and that is done through writing. Reports show this when a student says, "I wanted to do this or that, but this was a better choice for this reason. . ."
    Engineering documents are opinion pieces. They're a combination of professional judgment and appropriate analytical facts that support it. By using writing, the students just keep getting better at making connections between disciplines.
    The emphasis on both writing and activities is not limited to my courses but is important across the entire AE curriculum. The department is currently planning to extend the sequence of courses for undergraduates to five classes of structure, materials, and propulsion. AE 507, taken before 410 and 508, focuses on simple concepts. AE 430, the final course in the sequence, looks at the experimental characterization of the

project: it breaks down where the design's weaknesses are. We want to engage the other two classes in this type of discussion through reports that they will use.