

2006-1858: PORTFOLIOS IN ENGINEERING EDUCATION: WHAT DO THEY PROMISE AND HOW CAN THEY BE USED?

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Portfolios in Engineering Education: What Do They Promise And How Can They Be Used?

Introduction

Student portfolios have been listed as a possible means of assessment under the basic level accreditation criteria for ABET (Accreditation Board for Engineering and Technology) Engineering Criteria 2000. Since then, engineering educators and researchers have started to use portfolios in their teaching and are trying to explore the potentials of portfolios. Various efforts have focused on using portfolios in engineering instruction and the results of those efforts have been reported in the engineering education literature. This research provides educators useful information on how to use or adopt portfolios efficiently in their classrooms.

However, because of the diversity of the efforts to include portfolios in the engineering curriculum, it is difficult for new educators to gain a clear understanding of what they can learn from the previous studies and thus to decide how to design a portfolio assignment for their classrooms. Practical questions, such as “If I want to use portfolio for the purpose A, how should I design my portfolio curriculum”, can hardly be answered. The major reasons for the difficulties in effectively using student portfolios could be that (1) portfolios were defined differently, (2) the reasons for using portfolios were different; (3) the components that were included in the portfolios were different; and (4) the setting and instruction on creating portfolios were different. These variations in designing portfolios make it very difficult for new educators to quickly design a portfolio curriculum and accurately employ it in their classrooms.

This paper describes our efforts in collecting, summarizing, and comparing the design of portfolio assignments in order to provide a review of the practice of using student portfolios in engineering education. To achieve this goal, we will review eleven research papers to illustrate the broad range of portfolio use relevant to engineering education. The review of these papers will help engineering educators to understand the diversity of portfolio use in engineering education.

In the paper, we will first review the current literature on defining and classifying student portfolios. Using this review as a basis, we introduce and define the major dimensions of variations in the design and use of portfolios. These major design dimensions were used as criteria for us to collect and select eleven research and practice papers to maximally illustrate the diversity of portfolio use in engineering education. We then explain and compare these studies in detail and provide suggestions on the design and use of portfolios for engineering educators based on their pedagogical interests. Finally, we will discuss the research issues that are raised in our findings for the education researchers to further explore the possible pedagogical impacts of portfolios on engineering education.

Portfolios Definition

Portfolios have been widely and successfully used in other fields, such as architecture, art design, business, journalism, photography, writing and language learning. Comparatively, the use of

portfolios in engineering education is still new and the best way to use portfolios to enhance engineering education is still under exploration. In the fields of architecture and art, students create portfolios by collecting samples of their best work and organizing them into a portfolio. Then, students submit the portfolio to the instructor or a prospective employer for review and evaluation. Portfolios are also widely used in writing and language learning programs. In a writing program, students collect samples of their writing, which are often created over time, to show the changes and advancement of their writing skills. These two types of portfolios are considered to be the basis of the portfolios used in engineering discipline.

Besides these two commonly used portfolio models, there are several other types of portfolio models being suggested and used in the practice. Cress and McCullough-Cress¹ designed a student portfolio as a collection of student goals for learning, works in progress, peer and instructor feedback, and reflections on the work and processes. Gottlieb² pointed out that portfolio designs, contents, and purposes could take on many forms, all of which are educationally defensible. In order to clarify the variety of portfolios, he proposed a developmental scheme, which includes six prototype portfolio categories: collections, reflections, assessment, documentation, linkages, and evaluation. Each portfolio category signifies a distinct stage of development and has a set of specified criteria that shape its function.²

Thinking of creating portfolios as a learning strategy, Shackelford³ discussed four types of student portfolios based on their purpose: showcase portfolios, descriptive portfolios, evaluative portfolios, and composite portfolios. The showcase portfolios display students' best work; the descriptive portfolios contain both completed assignments and works in progress; the evaluative portfolios document students' understanding and mastery of specified skills; the composite portfolios show the team collaboration and group accomplishment.³ Different from Shackelford, Olds⁴ discussed two different approaches in terms of collecting the contents for the student portfolios: students could collect nonselective working materials that are required by the instructors, or selectively collect the documents produced in the class based on students' own judgment of what is most appropriate to include. The purpose of the former type of portfolio is to archive the students' class materials, while the purpose of the latter is to represent and/or showcase students' best work⁴

Other types of portfolios may be defined in terms of their purpose and orientation. Campell et al.⁵ identified three types of professional portfolios: process-folios, product-folios, and process/product-folios. The process-folios focus on learning process and document achievement and academic development over time. The product-folios characterize the growth of learning, skills, and abilities at a specific point in time and focus on well-developed products. The process/produce folios are hybrids that bring together the best finished work to showcase and the intermediate work to demonstrate the improvement in learning and skills over time.

The different portfolio models discussed above illustrate the diversity of the structure and purpose of portfolios used in education. However, since these efforts were done at different time and for different reasons, there is a significant degree of cross-over and overlap between the models. Although it is quite natural to have cross-over or overlap between categories², these overlaps make it difficult to clearly define or efficiently design a portfolio for a specific purpose. There are also concerns that since these portfolio models are not formulated in science,

technology, engineering, mathematics (STEM) related disciplines, they might be not applicable to engineering students, faculty, and programs.⁶

Selection of Portfolio Practices in Engineering Education

As we showed in the last section, educators are defining and using portfolios in a various ways. For new engineering educators, it can be helpful to see specific examples of the design and use of portfolios in engineering education.

To illustrate the use of portfolios in engineering education, we selected and reviewed eleven published academic papers that presented fifteen different studies of portfolio design and practice. The review and analysis of these papers will present a comprehensive picture of the research and development of using portfolios as an educational intervention.

Variations and Our Sampling Strategies

The diversity of portfolio definitions and uses makes it challenging to know how to design an effective portfolio program that fits the needs of engineering educators and students. For engineering educators who want to include portfolios in their teaching, it is very important to have practical and unambiguous advice on what types of portfolios could be brought to their teaching and what precisely they need to do in order to make the portfolios work efficiently in the classroom. Major questions that often drive the design and use of portfolios include:

- Context: In what situation are portfolios used in engineering education?
- Definition: How are student portfolios defined?
- Purpose: What is the purpose of using portfolios?
- Content: What are the artifacts being included in a portfolio?
- Structure: How are the artifacts put together to form a portfolio?
- Selection: How are the artifacts selected? By whom?
- Interaction: What are the interactions between students and instructors in creating portfolios?
- Evaluation: How are portfolios evaluated?

In addition, educators may also want to know what they and their students could gain by creating a specific type of portfolio (i.e., benefits and drawbacks). They may also have specific questions about the pedagogical effects of using portfolios and the credibility of claims about those effects in terms of the data or observations that support those claims:

- Benefits/Drawbacks: What are the benefits of using portfolios, and what are the drawbacks?
- Methodology: How were those benefits/drawbacks concluded by researchers or educators?

The selection of the reviewed papers was based on the above questions. Answering these questions could not only provide new educators with a clear understanding of what is known about portfolio design, but also help them clearly and maximally distinguish the differences in portfolio use as reported in the literature. Since we are interested in providing engineering educators with information about using portfolios to support student learning, we only selected papers that described a specific design or practice of using student portfolios. Papers that talked

about portfolios, but contain no information about an actual design or use of portfolios, were not included in this review.

We collected eleven papers that were published in engineering education journals and conferences. The major sources of papers include the *Journal of Engineering Education (JEE)* and the proceedings of the two major engineering education conferences, the *American Society of Engineering Education annual conference (ASEE)* and the *Frontiers in Education annual conference (FIE)*. This collection of papers is by no means comprehensive. The purpose of collecting and comparing these papers is to start with what we already know about how portfolios are used in engineering education and to provide suggestions or advice on the design of student portfolio assignments.

The Comparisons of Portfolio Designs

The papers that we selected come from a wide range of colleges and universities. Students who completed the portfolios also come from various engineering disciplines and represent a range of academic levels. The following sections will compare and discuss these various uses of portfolios from the perspective of the questions listed in the previous section.

Context

Student portfolios have gained significant attention from engineering researchers and educators. The studies of students portfolios in our surveyed papers were conducted within various disciplines, including electronic engineering⁷, software engineering⁸, agricultural engineering⁹, biological engineering⁹, aerodynamic¹⁰, chemical engineering¹¹, mechanical engineering¹², technical communication in the college of engineering¹³, and other mixed engineering disciplines.^{1 14 11} Students who created portfolios in these studies also are on different academic levels, from freshman students^{15 9}, sophomores⁷, to seniors.^{8 9} Studies in these papers provide a broad coverage of the context in which portfolios were used. New engineering educators or researchers could refer to similar cases in their design of portfolio curriculum.

In most of the papers that we reviewed, the portfolios were created for a specific course (eleven out of fifteen studies). The portfolio construction could take place at the different stages of the course, such as in the mid-semester⁹, in the midterm and at the end of the course⁷, only on the final stage¹⁵, or throughout the semester⁸ or the quarter.⁹ The portfolios could also be used to replace other assignments¹¹ The life cycle of the portfolio creation could exceed the boundary of the classroom. For example, Heinricher et al.¹¹ asked students to update the portfolios across the academic year. Students in Guan et al's study¹² created a retrospective course-based professional portfolio for a course that has been completed in the quarter prior to the current quarter. The portfolio creation could also happen in a broader context to include multiple parties in addition to students; for example Heinricher et al.¹¹ designed a portfolio program in which students discuss these portfolios with not only instructors, but also the departmental officials, such as academic advisors; Lappenbusch et al.¹³ designed a portfolio program that students discuss with their classmates in the procedure of creating their individual professional portfolios. This broad context in which students could create portfolios shows that portfolio design could be very

flexible and the portfolio curriculum could be adjusted based on different classroom or school settings.

Definitions

As we indicated in the previous section, there are various definitions of portfolios in use. For new engineering educators to understand how portfolios can be and are used in engineering education contexts, it is necessary to examine whether the authors define portfolios in similar ways.

The studies in the eleven papers that we collected show a consensus about the basic definition of a portfolio as a collection of student work. However, these studies are divergent on the general use of portfolios as “telling a story of achievement and growth” or simply “documenting what students have done in the class.” Two of the fifteen studies merely used portfolios to document students’ activities in the classroom.^{10 14} And, we found the functions of documenting the learning steps and demonstrating the achievement are very often coupled together in the portfolio design, which will be discussed in more detail in our discussion of the purpose and contents of the portfolios. The shared understanding of the portfolio makes it easier for new educators to acquaint the current practice of portfolio design and implementation in order to create their own design.

Purposes

In the papers we investigated, the researchers and educators were trying to use portfolios for various purposes, such as keeping record of student work or supporting student learning.

The majority of studies (twelve out of fifteen) designed portfolios to be evaluative portfolios as defined by Shackelford.³ Portfolios were used to assess students’ achievement^{9 7}, instruction efficiency^{1 7}, learning outcomes or objectives¹¹, levels of skill competencies¹⁰, and understanding of college experience and engineering profession.^{15 12 13} Two of the fifteen studies designed portfolios to be descriptive portfolios, for example, Upchurch designed a portfolio to simply document or describe what students have done⁸; Christy et al.⁹ designed a portfolio to document students’ thought processes in identifying the motivation for choosing engineering, choosing areas of interest, and learning fundamental concepts.

Although evaluative portfolios asked students to evaluate themselves or instructors on some aspects of learning or instruction, this evaluation was sometimes used as an approach to drive student learning. For example, Jalkio⁷ designed a portfolio assignment to motivate student reflection on learning, Guan et al.¹² and Lappenbusch et al.¹³ designed a portfolio assignment to support students in thinking explicitly about their professional preparedness, and Cress¹ designed a portfolio assignment to help students explore the relationship between course learning and life-long career development. The descriptive portfolios were also designed to promote student learning, for example, Upchurch’s portfolio⁸ was designed to help students focusing on learning processes and Christy et al.⁹ designed portfolios to identify the motivation for choosing engineering. These purposes show that a particular portfolio program could have multiple purposes depending on the educators’ focuses and interests.

Content

Given the different purposes for using portfolios, it is unsurprising that the portfolios also contained different types of content. The materials in the portfolios included diverse artifacts that were created by students, such as students' exams, assignments, project reports, and homework. In addition to those artifacts, students were often required to write an entry or narrative for each artifact or selected artifacts.^{6 9 11 12 13 15} Collecting materials and writing entries could be done once a time, or regularly. For example, Heinricher et al.¹¹ designed a portfolio to include biweekly written entries over an entire academic year; each entry was a response to a set of questions related to ABET outcomes with evidence and examples attached to the entry.

Furthermore, some portfolios required students to write a summative evaluation⁷ or a cover letter^{6 9 12 13} to explain the portfolio as a whole. For example, Guan et al.¹² and Lappenbusch et al.¹³ designed professional portfolios to include a professional statement in the form of a cover letter explaining students' understanding of their engineering profession. Students were required to provide evidence drawn from course and backing up the claims in their professional statement; each artifact was accompanied by an annotation to explain the artifact and its connection to the ideas in the cover letter. The purpose of writing evaluations or comments is to trigger students to think about the value of the materials that they evaluated and make reflections and connections. As we will discuss in the subsequent sections, reflection is a very important component of creating portfolios. Instructors should encourage students to reflect about their work and scaffold appropriate strategies so that students can improve their learning through thoughtful and efficient reflections.

In addition to including the artifacts that students created in the class, some portfolios were designed to include artifacts created by the instructors, such as the course syllabus¹⁵ or the instructor's feedback⁸, artifacts created by peers, such as evaluations of work and progress by peers¹, or artifacts created in out-of-class activities.¹⁵ For new engineering educators interested in designing portfolio curricula, we suggest that the portfolios include materials that students created as part of the class. Depending on the purposes and context of the portfolio, materials created outside of the classroom could be included as well.

Structure

After students collect the artifacts they will include in a portfolio, they need to assemble and organize those artifacts into a single coherent portfolio. About half of the studies that we reviewed specified the structure of the student portfolios explicitly. Most often, a summative evaluation or cover letter linked all the elements in the portfolio together. For example Jalkio designed the portfolio to include a summative report to make the connections between the exams (required artifacts) with the course objectives⁷; Christy et al.⁹ designed the portfolio for seniors and graduates students in agricultural engineering to include a summary paragraph reflecting about their overall experience with the course. Lappenbusch et al.¹³, Guan et al.¹², designed portfolios to include a cover letter to explain students' understanding of their engineering profession, which was explained and documented in the annotated artifacts.

In some cases, the structure of the portfolio was explicitly specified so that students could easily follow the instructions. For example, in Erikson's showcase portfolio¹⁵, the format includes the title page, the table of content, introductory statements, documentation and reflective commentaries, and closing summary. In Guan et al's professional portfolio¹², the format was specified to include three parts, which are a cover letter, artifacts, and annotations to the artifacts.¹² A pre-defined structure provides students with guidelines for collecting materials and creating the portfolio so students could focus more on reflecting about the topic of their portfolios.

Selection

Although the portfolio is often designed to promote student learning, it is often the instructor who defines what is to be included in the portfolio. In five out of fifteen studies, including two instances of descriptive portfolios, the portfolios were non-selective in that the artifacts to be included in the portfolio had been pre-defined. For example, Jalkio⁷ designed the portfolio to include all the graded examinations; Christy et al.⁹ designed a portfolio program for freshman bioE engineering students to include the engineering units, report writing, presentation, lab demo chosen by the instructor and narratives for the selected assignment; Upchurch⁸ designed the portfolio to include all materials that student submitted during the course; Cress¹ required the portfolio to include all students' work in the course.

Three studies used hybrid portfolio assignments that involved a mix of artifacts that were specifically required by the instructor and artifacts that students chose themselves. In the portfolio program designed by Williams⁶, the instructor required students to include certain documents in their portfolios, but also allowed students to choose and include additional materials that showcased their best work. The portfolio designed by Knott¹⁴ was more adaptive in that the freshmen students were required to include one specific assignment in their portfolios but were allowed to choose all of the other material they wished to include. For the portfolios in the other seven studies, students were given the freedom to choose all of materials to include in their portfolios as long as these materials met the instructors' general guidelines.

Interaction

During the period when students are engaged in constructing the portfolio, interaction between the students and the instructors can be very helpful in supporting students' efforts. Of the fifteen studies we reviewed, twelve had feedback between students and instructors as an explicit design feature. For example, Upchurch's portfolio program⁸ was designed to have instructors provide feedback to students on their portfolios, and also have discussions among students themselves; Christy⁹ designed the course-based portfolio program to have students not only obtain feedback from the instructor, but also allowed students to resubmit their revised portfolios; Mourtos¹⁰ designed the portfolio program to also include a review cycle similar to Christy in which instructors gave feedback about a draft portfolio and students were allowed to rework the assignments and include both the original and revised versions in their portfolios. The interaction between the students and instructor also varies in time, for example, Knott's portfolio¹⁴ for freshman provided minimal interaction between the student and the instructor in that the instructors only provided suggestions on about organizing the materials, while Heinricher's

departmental portfolio¹¹ included periodically scheduled opportunities for instructors to examine the portfolio and give feedback to students. The interaction between students and instructors could substantially support the students' effort of creating portfolios by helping to sustain student interests and integrate the portfolio into the instructional package.

Evaluation

Although the portfolio is often designed to help students engage in self-assessment, there is very little information reported on how the educators in the studies evaluated the portfolios themselves. Seven of fifteen studies mentioned that the portfolios were evaluated after they were submitted. Two studies mentioned that the submitted portfolios were graded for credit.^{9 10} Only six of the studies described detailed criteria for evaluating student portfolios. The criteria or rubrics were not consistent and combined with different elements. Rubrics were designed to be a mixture of completeness, organization and creativity⁹, of completeness, quality, and depth¹¹, or of content, internal consistency, and writing.¹² Some rubrics were designed based on program objectives⁶, course efficiency reflected in the portfolio¹, or learning outcomes addressed.¹¹

In the context of a course where the portfolios were evaluated, the evaluation accounted for various percentages of the total grade. For example, Christy designed the portfolio to account for 50% total grade in one of her study and 100% total grade in her another study⁹ Where as Mourtos¹⁰ designed the portfolio to account for 65% grade. In such cases, students would treat the portfolio seriously as a class assignment and spend more effort to create it.

Comparing the Benefits and Drawbacks of Portfolio Assignments

When students were required to include most of their work into the portfolio, an obvious benefit of creating the portfolios is for students to archive and review their work. This benefit was mentioned in several studies. For example, students in Upchurch et al.'s study⁸ thought one of the main benefits of creating a portfolio was to archive assignments and to be able to review their work. Knott¹⁴ reported that students saw being able to keep a record of achievements and job experience as one major advantage of creating a portfolio. Heinricher¹¹ reported that students often highly value the portfolio as a rich source of documentation of learning related to their career goals. Students felt that it was important to document not only the final project, but also the process leading to the final project.¹⁴ Students were reported to want a means of creating a record of achievements in a professional format.¹⁴ It was also notes that that student personal, academic, and professional development throughout the progress of a course were also well demonstrated in the process of creating portfolios.¹⁵ It was suggested that assembling portfolio materials helps students see what they were able to accomplish and what they learned, which provided positive affirmation and instilled self-confidence.¹⁵

As we indicated before, portfolios have been used in disciplines other than engineering. The use of portfolios in engineering education was initially driven by ABET criteria, which identified portfolios as one of the assessment tools. Erickson¹⁵ explored the efficiency of portfolios in assessing classroom instruction. He found the portfolio could help educators determine if the student can apply the new knowledge. The portfolio also assisted in demonstrating both broad and in-depth comprehension and competence of students relating to course objectives. The

portfolio is also useful as a venue for student reflection, which catalyzes students' assessment of their own competencies, understanding and progress in the course.

Researchers have also been trying to explore the learning benefits of portfolio construction. This goal is represented in the papers we reviewed. The majority of studies that we surveyed mentioned learning when they discussed the benefits of using portfolios, although the researchers were touching on different aspects of learning. For example, Christy⁹ reported that the majority of students thought portfolios enhanced their learning. In Jalkio's study of course portfolios⁷, which included graded exams and summative evaluations, the authors noted that students were commenting on having a better understanding of what they learned after making the portfolios. Cress's course portfolio¹ about quality management was reported to create a shared vision and common learning goals, which in turn promoted learning and heightened awareness of systems. Erikson¹⁵ saw that students took a more active role in the learning process when they were asked to create a portfolio in the classroom.

Some studies highlighted the interaction between students and instructors and between students and their peers. In such cases, portfolios were mentioned as a way to facilitate team functioning in that the students were able to provide and receive feedback.⁸ The portfolios allowed students with diverse backgrounds and learning styles to flourish in the course.¹⁰ Students felt that sharing portfolio elements and receiving feedback might aid the learning process.¹⁴ Based on students' comments, the combination of team effort and portfolio assessment gave instructors a much better idea about what learning is going on in the course and how relevant it is to the work world and life long learning.¹⁴

Portfolios are also considered to impact career development and life-long learning in ways that are far beyond the scope of the course curriculum. For example, in Cress's study in a quality management course¹, students were reported to appreciate the opportunity to make their personal vision more explicit. In a different study¹⁴, upper-level students were reported to use e-portfolio to develop a resume for their career development (something that was not required by the instructor.) Heinricher¹¹ mentioned that the portfolio could increase students' goal-directedness and self-reflection related to learning and professional development.

Besides the benefits that portfolios can provide, there are also drawbacks to using portfolios in the classroom. Jalkio⁷ mentioned that using portfolios can create extra work for faculty, and Mourtos¹⁰ reported that faculty need to spend additional time in portfolio assessment. These observations about the time demands of portfolio use are not surprising since using portfolios requires faculty to create the curriculum, explain it to students, provide students with feedback, and finally grade the portfolios.

In addition to the issue of extra work, researchers found that there are other obstacles to using portfolios in the classroom, obstacles which require attention and time. Jalkio⁷ reported that when the portfolios are newly introduced to a classroom, it is not easy for students to understand the portfolio assignment. Mourtos reported that the most reflection the students made have lack depth and understanding of what the portfolio exercise is all about. This implies that faculty may need to expend extra time helping students understand the potential of creating a portfolio. Knott¹⁴ found that students do not expect extensive guidelines if creating a portfolio simply involves

reflecting, however, students do need more guidelines if an e-portfolio is integrated into the curriculum. In addition to providing students with guidelines, it is also necessary to develop rubrics for evaluation of the e-portfolio.¹⁴

In order for portfolios to support student learning, it is necessary for students to reflect on their work. However, students did not mention using the portfolio as a reflective tool if it not explicitly pointed out to them.⁸

Although portfolios allow the students to take more responsibility for their learning¹⁰ by selecting materials on their own, and engaging in self evaluation and reflection, it was found that students are reticent to engage in self-directed learning⁹ and they are not used to “being responsible” for their learning.¹⁰ Students often only include materials that are required by the faculty¹⁴, which implies that more incentives are required to motivate students to personally select materials and reflect on their learning experience.

Portfolios can also have negative effects on the classroom structure. In Heinricher’s study with twenty-three students from various majors¹¹, these students were required to make biweekly written entries to address ABET outcomes in their portfolios. The authors of the study reported resulted serious attrition in participation. Only fourteen of twenty-three students continued the study, and only eleven submitted the final portfolio. In another of Heinricher’s studies in which students were working together with course instructors and departmental advisors to create portfolios, students made comments that they needed more structure and mentoring to sustain interest in the face of competing time demands.¹¹ This implies that students may need to see obvious benefits of creating portfolios in order to support their efforts, otherwise, a similar attrition could happen in the classroom. This negative effect could also be seen in Christy’s study in that the instructors received lower course evaluations for the course involving portfolio than for their other courses.⁹

Things to which educators should pay serious attention

Of all the benefits and drawbacks of portfolio use that were reported, some were based on students’ informal comments, while others were gained through formal data collection, such as formal interviews, surveys, and questionnaires.^{8 9 11} Issues and suggestions that were revealed or provided in the studies with more rigorous data collection might call for more attention than those merely based on students’ comments.

Formal interviews conducted in Upchurch’s study indicated that using portfolios as a reflective tool is not obvious for students.⁸ This means that new educators who want to take advantage of the benefits of reflecting, such as promoting goal-directness towards learning and career development, should explicitly suggest and encourage students to reflect on their learning and maybe provide scaffolds to support students’ self-assessment. Lappenbusch et al.¹³ observed in their study that portfolios functioned as productive boundary objects in student discussions of their professional skills and abilities. This could imply that group discussions of their portfolios may help students reflect.

Surveys and interviews in Christy's studies revealed student reticence in self-directed learning.⁹ This obstacle could greatly hinder students' motivation to direct their own learning and maybe even their motivation to create thoughtful portfolios. Students in this study suggested that instructors should explain how and why portfolios enhance learning, provide an appropriate level of structure, and integrate portfolios into curriculum planning.⁹ In designing a portfolio assignment for mechanical engineering students, Guan et al. used a user-centered design methodology to design the portfolio assignment based on users' (students' and instructors') needs.¹² The portfolio assignment they designed helped students understand what they could do in creating portfolios and what they might gain by doing so.

It was also reported in Heinricher's study¹¹ that student attrition occurred because of lack of time, higher priorities, and lack of structure and guidance. A similar concern was raised in Christy's study as well.⁹ This problem is related to the general concern that the benefits of creating portfolios need to be explained explicitly and the instructor needs to design an effective time management strategy for students.⁹

What More Do We Need to Know?

The studies in the papers we surveyed show that there are many variations in how to design portfolios and portfolio assignments. This review paper is intended to provide a broad picture of what is known across various studies and what we might need to pay attention to. Two main concerns that could not be answered by the studies in this survey include:

- Could I get benefit "x" by doing that?

None of the studies that we surveyed clearly indicated direct cause-effect relationships between a particular portfolio assignment and associated pedagogical effects. Various benefits were mentioned for each of portfolio configuration; however, to understand how these benefits were gained by students, more experiments would need to be done. For example, researchers or educators could observe what happens during the process of creating portfolios to understand how students progress through a portfolio assignment. For example, Lappenbusch and his colleagues used community of practice theory to understand what happened in a classroom where students were discussing portfolio creation with their peers.¹³

- Which combination works best in a specific situation?

Although there were lots of variations in designing portfolios and portfolio assignments, the paper authors rarely indicated a rationale for combining several design features, which makes it difficult for new educators to decide which components they should include in their own design. For example, both Jalkio and Upchurch asked students to create a course portfolio with summative evaluations their studies. Jalkio only required students to include graded examinations while Upchurch asked students to include all materials student submitted during the course. However, since the authors did not indicate why they choose those components (graded exams vs. all materials), other educators may not know which one they should choose in their situation.

Conclusion

In this paper, we presented a review of the current practice of using portfolios in engineering education. We first reviewed various definitions and classifications of portfolios to show a diverse view on the structures and purposes of portfolio design. We then surveyed eleven papers that were published in major engineering education venues. These papers include fifteen studies that vary in terms of engineering discipline and student academic level.

Our review of the use of portfolios in these studies showed that researchers and educators share a similar understanding of the basic definition of portfolios as a collection of student work; however, the purpose, content, and structure of portfolio activities are diverse. This diversity indicates that, on the one hand, new educators have a great deal of flexibility in creating portfolio assignments. On the other hand, this could be a problem because educators may not know which configuration of an assignment is best for their situation.

The review of the benefits and drawbacks of portfolios as documented in these papers indicated that portfolios can provide a good record of student achievement, support select assessment, and create opportunities to impact student learning, team collaboration, and career development. The review also indicated that educators should provide support for students when they are creating their portfolios in order to cultivate the possible benefits of portfolio use and avoid possible negative effects.

Acknowledgements

The preparation of this work was supported by the National Science Foundation (REC-0238392, “Using portfolios to promote knowledge integration in engineering education”). The authors wish to thank Yi-min Huang, Matt Eliot, Roxane Neal as well as the anonymous ASEE reviewers for their comments on the work presented in this manuscript.

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Appendix I: Review of Papers:

PAPER	Jalkio 02 ⁷
DEFINITION	A collection of students' work
PURPOSE	1. As students' self-assessment of their achievements 2. To assess the efficacy of class instruction 3. To motivate students' reflection on learning
CONTENT	Graded examinations and summative evaluations
STRUCTURE	Summative reports make the connections between the exams and course objectives
SELECTION	Instructor determined the major content; Students select other materials
CONTEXT	In the course (at the mid-term and end of the course)
INTERACTION	Unknown (Unknown means the details was not indicated in the paper)
EVALUATION	Unknown
BENEFITS/ DRAWBACKS	(+). students having a better understanding of what they learned (-). extra work for faculty (-). students do not understand the assessment assignment
METHODOLOGY	Based on students' comments

PAPER	Upchurch 02 ⁸
DEFINITION	A collection of student's work that tells a story of achievement or growth across a variety of content and skill areas.
PURPOSE	Help students to focus on their learning processes
CONTENT	All materials student submitted during the course along with feedback from instructor
STRUCTURE	No specific structure. Items that are submitted together are grouped together
SELECTION	Pre-defined course structure; No selection because everything is included
CONTEXT	During course throughout the semester
INTERACTION	Feedback between students and instructors and among students
EVALUATION	Unknown
BENEFITS/ DRAWBACKS	(+). students completing assignments and reviewing their work (+). facilitating team functioning (+). students are able to provide and get feedback (-) students did not mention using the portfolio system as a reflective tool
METHODOLOGY	Formal interview with 9 students; Interviews were conducted by psychology students

PAPER	Williams 01 ⁶
DEFINITION	A purposeful collection of student work that exhibits to the student (and/or others) that student's efforts, progress, or achievement in a given area.
PURPOSE	To document student learning in communication
CONTENT	1. Assignments, projects, and reports 2. A cover letter or a reflective statement for each document to explain the document and make the case for the relevance of the document to particular learning objectives
STRUCTURE	Unknown
SELECTION	Instructor or Students
CONTEXT	Unknown
INTERACTION	1. For the course portfolio, instructor can require specific documents, including assignments, project, and reports 2. Students can decide which documents showcase their best work
EVALUATION	Evaluation rubrics developed based on the program objectives
BENEFITS/ DRAWBACKS	(+) students wished to include more evidence of their work, not only the final research report that was required. (+) students took full ownership for their portfolios (-) the best students were constantly reflecting on their learning; however, majority of students couldn't do reflection naturally. (+) reflection provides students with a significant learning opportunity that only comes with the use of portfolios.

METHODOLOGY	Unknown
PAPER	Christy 98 ⁹
DEFINITION	Same as above
PURPOSE	Showing the level of achievement on competency topics
CONTENT	1. Homework, lab reports, examination, presentation, and team project 2. A cover page, competency matrix, referenced work, and a self-assessment narrative
STRUCTURE	Using the cover page to explain each item and a concluding summary to reflect on the overall experience of the course
SELECTION	Student decide what to select and how to evaluate each selection relative to the each competency topic (information, knowledge, application and analysis, and wisdom)
CONTEXT	In the course; Throughout the quarter
INTERACTION	Through resubmission and feedback process
EVALUATION	100% of grade
BENEFITS/ DRAWBACKS	(+) majority of students thought portfolios enhanced their learning (-) instructors received lower course evaluation for this course relative to other courses (-) student reticence in self-directed learning
METHODOLOGY	1. End-class survey, mid-quarter interview 2. In-class discussion, student questionnaires, external review, and class committees

PAPER	Christy 98 ⁹
DEFINITION	Same as above
PURPOSE	Documenting the student' thought processes in identifying what motivated them choose engineering, choosing areas of interest, and learning fundamental concepts
CONTENT	1. Engineering units, report writing, presentations, lab demos chosen by the instructor (graded as satisfactory or better) 2. Self-assessment narrative for the included assignments
STRUCTURE	Unknown
SELECTION	The instructor decided what to include in the portfolio
CONTEXT	Unknown
INTERACTION	Portfolios were checked at mid-semester
EVALUATION	Evaluation criteria: completeness, organization, and creativity; 50% of total grade
BENEFITS/ DRAWBACKS	(+) majority of students thought portfolios enhanced their learning (-) instructors received lower course evaluations for this course relative to other courses (-) student reticence in self-directed learning
METHODOLOGY	1. End-class survey, mid-quarter interview 2. In-class discussion, student questionnaires, external review, and class committees

PAPER	Cress 95 ¹
DEFINITION	A systematic and purposeful collection of student learning goals, works in progress, peer and instructor feedback, and reflections on the work.
PURPOSE	1. To support Steven Covey's seven habits and Peter Senge's five disciplines 2. To promote continuous improvement for both students and instructors 3. To clarify the relationships between course learning and life-long career development
CONTENT	Could include student personal mission; learning goals; course mission statement; whole class leaning goals; seminal work in the course with periodic reflection papers asserting progress toward goals Could include feedback with revisions and changes on the part of the students as well as suggestions for the instructor Could also include evaluations of work and progress by peers and instructor.
STRUCTURE	Unknown
SELECTION	The portfolio structure is pre-defined (details were not provided)
CONTEXT	In the course (details were not provided)
INTERACTION	Instructor helps students to produce course plan and common learning goals

EVALUATION	1. Instructor creates feedback loop for measuring the course effectiveness based on students' reflection paper 2. Students discuss the reflection papers in class
BENEFITS/ DRAWBACKS	(+). Students appreciated the opportunity to make their personal vision more explicit (+) Creating a shared vision and common learning goals promoted learning and heightened awareness of systems (+) The combination of team effort and portfolio assessment gave instructors a much better idea about what learning is going on in the course and how relevant it is to the work world and life long learning skills
METHODOLOGY	Based on students' comments

PAPER	Mourtos 97 ¹⁰
DEFINITION	Un-defined (seems to be a documentation portfolio that collects mandatory and selected student works)
PURPOSE	Having students demonstrate a minimum level of competence in all basic skills and allowing students to have having more responsibility for their own learning
CONTENT	1. Mandatory assignments and tests 2. Other materials that students chose based on their preferences (all assignments were previously graded) both old and new revisions of assignments were included in the portfolio
STRUCTURE	Students included reflections on the materials contained in the portfolio.
SELECTION	Instructor decided the mandatory content; students decided their additional content A matrix was used to match student's competence with specific assignments in the portfolios.
CONTEXT	In the course
INTERACTION	Instructor gives feedback on assignments; students could rework on the assignments and include both the previous and revised versions in the portfolio.
EVALUATION	Criteria unknown; 65% of grade
BENEFITS/ DRAWBACKS	(-) most reflections students made lack depth and understanding of what this exercise is all about (+) Portfolios allow the students to take more responsibility for their learning (+) Portfolios allow students with diverse backgrounds and learning styles to flourish in the course (-) Portfolio assessment requires more faculty time (+) Students felt good about being able to choose their own assignments and have more flexibility concerning content to be included in the portfolios (-) Students are not used to "being responsible" for their learning
METHODOLOGY	Based on students' comments

PAPER	Knott 04 ¹⁴
DEFINITION	A document of students' knowledge, skills, and achievements from coursework and extracurricular activities.
PURPOSE	To support student reflection and the thoughtful accumulation of academic work over time.
CONTENT	For fifteen mandatory freshman students: at least one mandatory project from the current course and any other materials they wished to include For four MinEng (mining and minerals engineering) students in: no requirements on the content and use of the portfolio For one civil eng student: a pre-determined assignment in ePortfolio
STRUCTURE	Unknown
SELECTION	Freshmen portfolios: mandatory materials from the instructor + materials selected by students MinEng (mining and minerals engineering) students' portfolios: students made all selections CivilEng students' portfolio: mandatory materials from the instructor

CONTEXT	Freshmen portfolios: associated with a course MinEng students' portfolios: no specific context CivilEng students' portfolio: associated with a specific course
INTERACTION	Minimal interaction: faculty only provided suggested locations for students to store the materials
EVALUATION	Unknown
BENEFITS/ DRAWBACKS	(-) Most students included only materials required by the faculty (+) Upper-level students use e-portfolio to develop resume (not required by the instructor) (+) Students need more guidelines if ePortfolio is to be integrated into curriculum (+) Students may desire to create a record of achievement in a professional format (+) Students see the major advantages as being able to keep a record of achievement and job experience (+) Students felt it was important to document not only the final project, but also the process leading to the report (+) Students felt that sharing portfolio elements and receiving feedback might aid the learning process (-) Mixed reaction to the idea of mandatory ePortfolio in the class (-) Assignments need to provide students with guidance; Assignment creators need to develop rubrics for evaluation of ePortfolio assignments
METHODOLOGY	Students' comments shared with faculty

PAPER	Heinricher 02 (Study #1) ¹¹
DEFINITION	Undefined (seems to be a document of students' reflections on ABET outcomes-related educational goals.)
PURPOSE	To promote student learning and to provide useful outcomes assessment data
CONTENT	Students make biweekly written entries over an entire academic year. Each entry was to respond to a set of questions concerning a ABET outcome. Students submit a physical portfolio at the end of the year.
STRUCTURE	The final portfolio contains 12 written entries, each consisting of responses to the questions, plus the appropriate evidence
SELECTION	Students selected the items that would represent the evidence
CONTEXT	Across the academic year
INTERACTION	Faculty provide on-demand assistance relative to understanding and completing the assignments, kept track of submissions
EVALUATION	Students evaluated their own portfolios
BENEFITS/ DRAWBACKS	(+) Students felt portfolio to be beneficial (+) Positive about the value of portfolios for increased organization, increased awareness of educational attainment, and valuable reflection on and clarification of goals (+) Increased students' goal-directedness with respect to learning and career, and their self-reflection related to their learning and professional development (+) Highly value portfolio as a rich source of documentation of their learning achievements related to their career goals (-) Serious attrition in participation (only 14 of 23 continue the study, only 11 submit the final portfolio) because of lack of time, higher priorities, and lack of structure and guidance
METHODOLOGY	Written surveys and group interviews in the middle and near the conclusion of the participation in the project; their own evaluation of the portfolios

PAPER	Heinricher 02 (Study #2) ¹¹
DEFINITION	Undefined (seems to be a document of students' reflections on ABET outcomes-related educational goals.)
PURPOSE	To promote student learning and to provide useful outcomes assessment data
CONTENT	1. For chemistry course: all students' work in the course and self-assessment of performance on selected tests and assignments

	2. For calculus course: portfolio entries responded to a different set of questions each week
STRUCTURE	Unknown
SELECTION	All mandatory by the instructor
CONTEXT	In a course
INTERACTION	The portfolio replaced other assignments; instructors periodically provided students with preliminary feedback; portfolios were examined periodically and graded at the end of the term based on completeness, quality, and depth.
EVALUATION	Unknown
BENEFITS/ DRAWBACKS	(+) It was manageable for professors to develop and grade the portfolios (+) May be a feasible way of getting widespread student participation
METHODOLOGY	Instructors' comments

PAPER	Heinricher 02 (Study #3) ¹¹
DEFINITION	Undefined (seems to be a document of students' reflections on ABET outcomes-related educational goals.)
PURPOSE	To promote student learning and to provide useful outcomes assessment data
CONTENT	Students prepare the portfolio entries for course credit; portfolio entries are supposed to address the ABET outcomes targeted by the instructor/advisors.
STRUCTURE	Unknown
SELECTION	Items jointly selected by the instructor and the students; instructor defined the goals of entries and students prepared the portfolio entries to address the ABET outcomes
CONTEXT	In a course with instructors and outside of a course with academic advisors
INTERACTION	Students and advisors have interactions around planning the portfolio (details unknown) Students, instructors, and advisors meet at the annual academic meeting to discuss the portfolios.
EVALUATION	The advisor and students rate the portfolio based on whether outcomes are addressed
BENEFITS/ DRAWBACKS	(+) Both students and faculty found the assignment manageable. (it replaces other course assignments) and worthwhile for learning and career planning (-) Assignment needs more structure and mentoring to sustain interest in the face of competing time demands
METHODOLOGY	A workshop was held to get feedback from advisors and students

PAPER	Erikson 98 (Study #1) ¹⁵	Erikson 98 (Study #2) ¹⁵
DEFINITION	A purposeful collection of student work that tells a story of the student's efforts, progress and/or achievement in given areas.	
PURPOSE	Letting students take a more active role in learning	Asking students to demonstrate what they have come to learn and understand about themselves, the college experience and the engineering profession
CONTENT	Anything and everything relating to the course should be included in their working portfolio; Each item accompanied by written commentary	Selected items representing highlights of what students have learned and/or accomplished
STRUCTURE	Students were asked to organize the materials around the five course objectives. Students were required to review their portfolios at least once a week. Students were encouraged to maintain a log or journal as part of their working portfolios.	The prescribed format for the showcase portfolio was: 1) title page; 2) table of contents; 3) introductory statement; 4) documentation and reflective commentaries; and 5) closing summary.
SELECTION	Students selected items that would best represent their progress in the course.	Students selected the most personally meaningful and significant pieces

		from course activities.
CONTEXT	During course	During course (final stage)
INTERACTION	The instructor provided a list of sample activities and resources for each course objective in the syllabus.	Each student would personally submit his showcase portfolio to an instructor. A brief (5-7 minute) conference was held to review and interact relative to the content.
EVALUATION	Course instructors established periodic times to review working portfolios	Discussion with each student.
BENEFITS/ DRAWBACKS	(+) The portfolio might help educators to determine if the student can apply the learned knowledge. (+) The portfolio assisted in demonstrating both the broad and in-depth comprehension and competence of students relative to course objectives. (+) The portfolio catalyzed students to assess their own competencies, understanding and progress in the course. (+) The degree and substance of reflection demonstrated by students for the course improved over previous semesters when journaling was the sole reflective tool used. (+) The way students developed personally, academically and professionally throughout the progress of the course was well demonstrated (+) Students took a more active role in the learning process (+) The assembling of portfolio materials demonstrated to the students what they were able to accomplish and what they learned. In most cases, this provided positive affirmation and instilled self-confidence.	
METHODOLOGY	Unknown	Unknown

PAPER	Guan 05 ¹²
DEFINITION	A purposeful collection of student work that tells the story of the students' efforts, progress, or achievement in a given area
PURPOSE	To promote student learning in a specific course as well as increased understanding of the engineering professional discipline
CONTENT	A cover letter, 3-4 selected artifacts and annotations
STRUCTURE	A cover letter explains the themes of the portfolio; each theme is embodied in an artifact; the annotation to the artifact explains the artifact and the connections between the artifact and the theme.
SELECTION	Students decide on the themes and the artifacts.
CONTEXT	The portfolios were created relative to a course, although the study occurred the quarter after students received their grades
INTERACTION	No interaction
EVALUATION	The portfolios were evaluated based on content, internal consistency, and writing quality.
BENEFITS/ DRAWBACKS	(+) Increasing students' appreciation of instructional design. (+) Helping students understand course objectives and knowledge structures. (+) Helping faculty understand students' perspectives, learning, and understanding. (+) Motivating faculty to improve their teaching. (+) Motivating students to communicate with faculty about their learning.
METHODOLOGY	Interview with students and the instructor

PAPER	Lappenbusch 05 ¹³
DEFINITION	A purposeful collection of student work that tells the story of the students' efforts, progress, or achievement in a given area
PURPOSE	To provide a structured yet flexible work environment in which students developed and evaluated their individual skills and interests in intellectually innovative ways
CONTENT	A cover letter, 3-4 selected artifacts and annotations
STRUCTURE	A cover letter explains the themes of the portfolio; each theme is embodied in an artifact; the annotation to the artifact explains the artifact and the connections between the artifact and the theme.

SELECTION	Students decide on the themes and the artifacts.
CONTEXT	Inside the classroom (a quarter long program - the Technical Communication Professional Portfolio Program (TC3P))
INTERACTION	Students met weekly to share their progress on their portfolios, and their understanding of the profession more broadly.
EVALUATION	The portfolios were evaluated based on content, internal consistency, and writing quality.
BENEFITS/ DRAWBACKS	(+) The portfolio program informed pedagogy by illustrating how typical TC students engaged in learning in a cooperative atmosphere while creating a reflective, online synthesis of their education in a peer-led group setting (+) Group production occurred (+) Reflection occurred sporadically, with no discernable pattern by week or participant
METHODOLOGY	Field notes of class discussion