2006-2047: TRACING STUDENT DEVELOPMENT DURING CONSTRUCTION OF ENGINEERING PROFESSIONAL PORTFOLIOS

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Tracing Student Development during Construction of Engineering Professional Portfolios

Abstract: Engineering students undertake the learning of a deep and complex discipline. In addition to a large amount of difficult content knowledge, their growth into engineers entails understanding the role of their engineering discipline in society, the profession of engineering as a whole and perhaps most difficult, their own places in both their discipline and their profession. In this paper, we report on a study investigating the potential of portfolio construction (specifically construction of professional engineering portfolios) for promoting and advancing students' growth into engineers.

Introduction

Engineering students undertake the learning of a deep and complex discipline. In addition to a large amount of difficult content knowledge, their growth into engineers entails understanding the role of their engineering discipline in society, the profession of engineering as a whole and perhaps most difficult, their own places in both their discipline and their profession. As a community, we need to develop innovative pedagogies to support all of these aspects of student development and to understand the impacts of such pedagogies.

In our work, we are exploring student construction of professional portfolios as one such pedagogical intervention[1-2]. In these portfolios, students describe their preparedness for engineering practice and provide evidence of their preparedness by drawing on experiences from across their curriculum. These portfolios include an overarching professional statement, artifacts illustrating their engineering skills and abilities (e.g. circuit design) and personal traits (e.g. leadership), and annotations to properly contextualize those artifacts for a specific professional audience (examples can be seen at http://courses.washington.edu/engrport/). Our goal in supporting this portfolio construction process is not to support assessment, as with many other portfolio efforts, but rather to create opportunities for learning and development.

We believe that portfolio construction offers a powerful variety of learning opportunities that leaves the portfolio creator more knowledgeable than she/he was prior to the portfolio construction activity. This belief comes from considering portfolio construction as a writing activity with the potential to transform the content knowledge about which the author is writing. Given that the creation of a portfolio involves writing about oneself, particularly one's own experiences and one's sense of belonging to the profession, the theory suggests that portfolio construction has the potential to transform, among other things, one's understanding of one's experience and one's sense of how they fit in the profession.

This paper reports a study investigating this potential of portfolio construction. The rest of the paper is organized as follows. In the background section, we provide additional detail on the theoretical framework guiding our work culminating with an identification of the specific research questions addressed in this paper. The method section provides detail on the context for our study (a class in which students were engaged in construction of professional portfolios) and discusses the larger study design from which this paper is drawn. In the results, we provide evidence of the kinds of learning opportunities we identified in the data. The paper closes with interpretation of the results and a discussion of the current direction of our work.

Background

In one of our pilot studies, we asked a freshman student working with us to create a professional portfolio in which she was to demonstrate how the assignments from one of her classes provided evidence of three or more aspects of her preparation for professional engineering practice. She chose her calculus class and proceeded to try to explain how the assignments in her calculus class provided evidence of relevant professional skills. After some period of floundering, she reported that she could not explain this issue to others, because she did not understand it herself. As a result, she decided to visit the professor during office hours and ask him about the link between math and professional engineering practice. This anecdote illustrates the interplay of two critical issues underlying our interest in professional portfolio construction as pedagogy: the theory of writing as a knowledge transforming activity and the nature of the knowledge that is embodied in a portfolio.

<u>Writing as a knowledge transforming activity.</u> Scardamalia, Bereiter and their colleagues explain how the writing process can transform knowledge, not just relay it[3-5]. Though Scardamalia and Bereiter focused primarily on traditional writing, not on portfolios, the larger issue was that of creating a written composition based on an understanding of a body of knowledge.

To summarize their theoretical view, writing has the potential to lead to learning through problem solving, in which solutions to problems represents new knowledge. In particular, they focus on two interwoven types of problem solving (rhetorical problem solving and content problem solving). Rhetorical problem solving involves the problems of audience, purpose and genre specific to the composition. For example, a problem of the form "how do I best explain this content to the audience given the rules of the genre I am using" represents an example of a type of rhetorical problem. Content problem solving involves the writer seeking a better personal understanding of the underlying domain or content knowledge associated with the composition. In practice, this could take the form of a writer engaging in background research because of a realization that his/her existing content knowledge is insufficient to achieve his/her rhetorical goals.

A key to Scardamalia and Bereiter's framework is the idea that development of a composition involves composers engaging in a synergistic intellectual movement back and forth between the rhetorical and content problem solving, reconciling problems which arise in one process by moving back to the other process. In other words, a problem arising in the rhetorical process may require the composer to move back to the content process to enhance his or her knowledge. In return, new knowledge gained in the content process may create issues with the current work in the rhetorical process, and thus a dialectic is generated between the rhetorical and content processes.

These ideas can be used to highlight certain features of the anecdote provided above. In that case, the student was engaged in the task of explaining to others how her math assignments provided evidence of preparedness for professional engineering practice (a rhetorical problem). After some period of struggling with this rhetorical problem, she decided she actually had a content problem—that of understanding these issues herself. This realization prompted her to visit the instructor with just these questions. The result of this content problem solving would be new insights about the role of mathematics in engineering practice. Later, armed with the

information gained from this content problem solving episode, she returned to the task of explaining her knowledge to others.

Scardamalia and Bereiter point out that this knowledge transforming approach to writing is not a characteristic of all writers or all writing situations. In fact, they note that this approach is more characteristic of expert writers. As a result, any efforts to use writing to promote learning should ensure that the desired learning is indeed happening. Given their theory, this documenting of learning could take the form of educators and researchers focusing on whether the writers are able to recognize, define, and solve both rhetorical and content problems. In the case of learning through portfolio construction, the issue is thus whether the students are capable of recognizing, defining, and solving problems that not only help them create a better portfolio but also problems that, when solved, leave them more prepared for professional engineering practice. The next section explores the content of a portfolio, in order to comment on the nature of the possible problems.

The types of knowledge that portfolio construction could potentially transform. The previous section suggests that any type of writing has the potential to lead to knowledge transformation, particularly for a sufficiently expert writer. In particular, the idea is that the knowledge that is transformed is the knowledge about which the composition is based.

In the case of the professional portfolio, one can generate hypotheses about the knowledge that could be transformed by looking to the defining features of the portfolio. In particular, in professional engineering portfolios, students describe their preparedness for engineering practice and provide evidence of their preparedness for functioning in a particular engineering discipline by drawing on experiences from across their curriculum and using those experiences as evidence of specific skills and knowledge important to the discipline. Portfolio construction is inherently a persuasive task in that the ultimate goal of the professional portfolio is to convince the reader that the author is prepared to contribute to professional practice. By unpacking these ideas, we can see that portfolio construction has the potential to impact knowledge dimensions such as knowledge of one's prior activities (which we term experiences), a general understanding of the skills necessary for engineering (which we term conceptions), and one's own sense of their belonging in the profession (which we term identity).

These ideas can also be used to shed light on the anecdote above involving a student explaining her calculus course. In particular, we can see that the writing activity involved the students' understanding of her class assignments (one form of experience), her understanding of engineering practice and the role of mathematics in that practice (conceptual knowledge), and her sense of her preparedness to function as an engineer (an identity issue). These ideas represent starting points for identifying the possible learning impacts of portfolio construction.

Research questions. While the above analysis suggests that construction of professional portfolios has the potential to be an activity resulting in critical types of knowledge transformation, it is important to recognize that there are several reasons why knowledge transformation might not result (e.g., novice writers, inability to identify relevant content problems). This set of observations points to the following research questions, which are addressed in the remainder of the paper:

- Concerning content problems: Does portfolio construction actually trigger identifying and solving of content problems? What types of content or knowledge problems emerge? What is the knowledge transforming potential of these problems, i.e., what aspects of knowledge are involved?
- Concerning rhetorical problems: Does portfolio construction trigger rhetorical problems? What types of rhetorical problems emerge? What is the knowledge transforming potential of these problems, i.e., what aspects of knowledge are involved?
- Mapping emergent knowledge categories to hypothesized knowledge categories: How do the identified problems map to the three issues of experience, conceptions, and identity?

Methods

These questions were investigated in the context of a course in which students constructed the type of engineering professional portfolios described in the introduction. Overall, the quarter-long course divided the overall portfolio construction activity into ten component activities. Students met weekly for a single three hour class session. Class time was used to provide peer review on portfolio components already drafted and to introduce the next activity. The activities in the cross-curricular program included: a) learning about portfolios in general, b) evaluating other portfolios, c) writing a professional statement, d) finding artifacts, e) deciding which artifacts to include in the portfolio, f) writing annotations for the artifacts, g) getting peer and professional feedback, and h) presenting the portfolio to others. The interaction amongst peers and the teaching faculty member provided ample opportunity to deeply explore the issues students faced, the component activities, and how those issues and activities interacted during the portfolio creation.

Six students participated in this study. These students included two seniors on the verge of graduating, two juniors who were building portfolios in order to get ahead of the game, and two graduate students. As a group, the students represented the disciplines of computer science, electrical engineering, chemical engineering, and technical communication. None of the students had constructed a professional portfolio, or any other type of portfolio, prior to the course. Although no definitive information was available to label these students as particularly strong students (i.e., GPA), we can infer that the students were motivated to think about their own preparedness given their voluntary participation in the course. Because of scheduling constraints, these students formed two three person sections of the course.

The research methods profiled in this paper are a subset of a larger study employing multiple data collection techniques including written reflections, audio-taped interviews, paper-and-pencil concept mapping, written surveys, and video-taped think-aloud protocols. For this paper, we use only the data provided in the weekly written process reflections completed by students. As a result, the data pertinent to this paper and analysis consist of 60 written weekly process reflections from the six student participants in the two course sections. In each weekly process reflection students responded to the following three questions: 1) how would you describe what you have been doing over the past week? 2) what challenges have you encountered?, and 3) what are you taking away? Though these questions do imply the possible existence of problems on the part of students, the questions do not lead students to relate certain kinds of problems or how they encountered each problem in their work. It is this exploration of the *kinds* of problems that students encounter that is the focus of the research in this paper.

Analysis proceeded in a grounded manner guided by the general issues of rhetorical and content problem solving and the knowledge dimensions of experience, conceptions, and identity. Researchers coded the responses on these process reflections as they were collected each week consistent with grounded theory methodology which requires coding to occur as data collection takes place in order to generatively build a preliminary understanding of thematic occurrences which can then be tested against subsequently collected data. Pursuant to this methodology, analysis was guided by research questions and previous experience and resulted in the systematic, thematic coding of data from the weekly process reflections written by students at the beginning of each class.

Though the data used for the analysis profiled in this paper are responses to three distinct questions on the weekly process reflection sheets, in reporting the findings we collapsed student responses and do not segregate them by question. We did this for two reasons. First, students did not always differentiate between questions and often, for example, wrote responses to the "How would you describe what you have been doing over the past week?" question that more accurately addressed the "What did you take away?" question. Second, the themes which emerged from the data set during our analysis cut across the questions and do not fit neatly within them.

Findings

In this section, we discuss examples of the types of content and rhetorical problems students encountered. In the section on content problem solving, we touch on two problems and then spend more of our effort profiling one particularly significant problem. In the section on rhetorical problem solving, we differentiate between two types of rhetorical problems—those that had potential to evolve into content problems and those that did not. Woven throughout our findings is the issue of how the problems map to the knowledge issues of experience, conceptions, and identity. Throughout, we illustrate the findings using passages from the process reflections. These passages are labeled with their week number and class section.

Evidence of content problem solving induced by portfolio construction. Despite the limitations of the dataset, the data did provide evidence of content problem solving (or at least problem identification) on part of the students. For example, we saw evidence of students reflecting on the importance of their experiences (the first quote below) and evidence of students thinking about conception of an engineer within their specific discipline (the second quote below).

> I was always doing a self-analysis of the value of each artifact and thinking top down. Class A, Week 4

> During the past week I've been thinking about what type of skills and knowledge are necessary for a good computer engineer. Class B, Week 2

The remainder of this section focuses on a particularly interesting content problem that emerged—students' ability to find utility in past coursework, and the relationship of this problem to the arguably more important problems related to their knowledge and beliefs about themselves. In general, several of the student statements suggested that students both sought membership in their engineering field and openly wondered if their engineering curriculum

provided opportunities for illustrating that membership and for considering how far they have come in becoming engineers. On numerous occasions, students doubted how well items such as course lab reports or projects represented their skills and abilities as engineers. Not only does this take their work in the professional engineering portfolio course out of the rhetorical and squarely into content problem solving, but it illustrates that students who were creating professional engineering portfolios were able to create a space in which they could potentially formatively question both their own progress and development as engineers and their past coursework's comparative incapacity to support asking those formative questions.

Simply put, these instances of doubting the value of their coursework as persuasive evidence of their professional abilities or membership in a discipline throws into sharp relief, albeit in a limited way, the issue of how supportive students found their engineering curriculum as they prepared for professional engineering practice. The following excerpts illustrate students' general difficulty in understanding how their studies encourage their transformation from engineering students to engineers.

> [I've been] Trying to think of how to group what I've learned from the courses into more general skills and areas of knowledge. Class B, Week 3

> [I am] Having to go through a project multiple times to identify topics I can talk about. Class A, Week 4

> It has been difficult trying to find projects from class that are complete enough to show some skills on my part. Class A, Week 4

> The main challenge has been to put my vision of electrical engineering into words. Class B, Week 3

Thus, as the students created their portfolios, students' doubts about the value of their academic work as engineering practice were revealed as something more than rhetorical considerations of how to persuade an audience comprised of "others" of the students' value as engineers. They sought to engage in content problem solving rooted in their understanding of themselves as engineers. However, they doubted whether previous coursework provided the capacity to support this important professional self-consideration. This emergent facet of the central theme of rhetorical and content problem solving suggests the portfolio activities provided students opportunities to explore engineering identity beyond previous traditional coursework.

> I have been picking out different artifacts and relating them to the skills my career path requires. The artifacts I chose had to be enough to at least explain how I have the skills needed. Class A, Week 4

> [I've been] Trying to explain projects and tying to artifacts the relevance of my experiences and the value of my work (the artifact). Class A, Week 5

> The artifacts show me how much I bring into the field. Class A, Week 4

Notice how each participant mentions how the nature of the portfolio construction activity (collecting or annotating artifacts) is tied to their ability to critically examine their past coursework in engineering. Here, participant students are relaying how the portfolio work itself has supported them in examining their own level of achievement in engineering and their confidence in calling themselves engineers. Notice how the portfolio or its activities are not at the center of the following quotes – the students and their content knowledge are.

> During the past week I've been thinking about what type of skills and knowledge are necessary for a good computer engineer. Class B, Week 2

> I beginning [sic] to see what skills and abilities I have developed or improved in my life. Class A, Week 3

> I had a couple interviews this week and the project has helped me articulate what skills I have and back them up with courses or other experiences. Class B, Week 6

Professionals, even emerging professionals, must be able to indicate their membership in a professional discipline by easily communicating how their individual work links them to the larger community of practice to which they claim membership. If, as indicated above, engineering students have difficulty or are simply unable to make these links through traditional curricular methods, then perhaps it is the nature of the work they perform as students which impedes their informed and facile entry into the engineering profession and not (or at the very least not only) the students themselves.

The nature of rhetorical problems induced by portfolio construction. While the above section demonstrates that we did find evidence of content problem solving, we also found extensive evidence of rhetorical problem solving. In reflecting on the rhetorical problems we identified, we found it useful is to distinguish between rhetorical problems that had the potential to lead to content problems and rhetorical problems which were unlikely to induce content problems. The former problems are particularly interesting because they represent places where an effective facilitator could really push students to explore the content problems significant to the rhetorical problems and thus help to maximize learning. The latter problems are significant in that they represent a cost of the portfolio activity in terms of problems that must be solved (and knowledge gained) that may or may not be important in the long run.

Below, we start with examples of the rhetorical problems that had the potential for transforming into content problems. The following examples illustrate the range of interesting themes that we identified concerning this issue. In each case, the student is describing a problem associated with making the portfolio (a rhetorical problem). Our categorization of these problems highlights the more general learning issue that the student would have had the chance to explore as a result of the rhetorical problem. The first three categories map relatively directly to the issues of experience, conceptions, and identity. The latter two categories involve combinations of these issues.

Significance of experiences (experience): Part of developing an engineering professional is the process of revisiting of prior projects in order to effectively

describe their salient features in the portfolio. The rhetorical problem could be described as "how do I capture the salient features of this project in my portfolio." For students who already possess a deep, flexible understanding of their prior project experiences, solving this rhetorical problem may involve only a revisiting of the various ways that they understood the project and selecting relevant aspects of their understanding. However, it is possible for a student to discover that they do not have a sufficient understanding of the project. This could be described as triggering a content problem of the form "what exactly was significant about this project" and/or "what exactly was this project about." The following quote shows evidence of this type of rhetorical problem, and thus evidence of the possibility of this type of content problem.

> I have found the several [sic] of my larger projects were not documented well and will unfortunately require some work before I can include them in my portfolio. In addition, I don't know *how well I can still explain* some of my past design projects… I made some of them 2 years ago. Class B, Week 4 (emphasis added)

Succeeding in workplace (conception). For many of the students, the goal of the portfolio was to help them achieve job/career related goals. The related rhetorical problem could be described as "how do I make choices in this portfolio to best support my chances of achieving my career goals (e.g., getting an interview, making a good impression)". Solving this problem requires some conception of what activities support one's chances in terms of achieving such goals. This suggests the possibility of a content problem of the form, "what exactly do I believe affects my chances of achieving my goals." The following quote shows evidence of this type of rhetorical problem, and thus evidence of the possibility of this type of content problem.

> Revision is going to be key to making this thing work. the writing has to be error free, concise, and captivating to reach my audience. If this is not the case I worry the portfolio will end up <u>hurting my chances</u> more than improving them. Class A, Week 6

Reconcile personality and engineering (identity). After reviewing a variety of example portfolios during one of the early course sessions, some of the students found that they enjoyed portfolios that concurrently helped the reader to understand the portfolio's author as an emerging professional and as a person. As a result, they adopted a rhetorical goal of the form, "how do I best communicate the meshing of my personality and my engineering preparedness in my portfolio." Solving this rhetorical problem without triggering a content problem would require the student to already have an understanding of how their personality and their engineering abilities are aligned. It is possible, however, that students would not have this knowledge and thus would find themselves needing to grapple with a content problem of the form, "how do my personality and my engineering abilities align." The following quote shows evidence of this type of rhetorical problem, and thus evidence of the possibility of this type of content problem.

> During the past week I struggled to write a professional statement. … In addition, I found it hard to *reveal much of my personality* in this 1st draft. I think I was too focused on the content (i.e. skills/values). Class A, Week 3 (emphasis added)

Deciding what is important: A key feature of almost any portfolio is that of selectivity. The portfolio does not contain all available information, but rather a selection of information that best supports the claims in the portfolio. As a result, portfolio construction involves rhetorical goals of the form, "what would be most important to show my audience" and "how can I structure my portfolio to highlight the most important items in the portfolio." For students who have already organized their ideas and experiences in terms of their importance, solving this rhetorical problem might not trigger an underlying content problem. However, it seems quite possible that this rhetorical problem could trigger students to grapple with content problems of the form, "what of my experiences do I believe are most important" and "what of my skills are most important." The following quotes show evidence of these types of rhetorical problems, and thus evidence of the possibility of these types of content problems.

> [I'm] Trying to think of what would be *more important to my audience* and how that should be ordered in my portfolio. Class A, Week 8 (emphasis added)

> I needed to determine the link label where I would *fit on the sequence*. Deciding on link labels. Class B, Week 8 (emphasis added)

> During the past week I struggled to write a professional statement. It was a difficult task for me, and I suspect for the others. It was relatively easy to brainstorm the values/skills that successful engineers possess - however, I found it difficult to focus on a few of those skills. Class A, Week 3

What experiences mean in context of practice. Another key feature of a professional portfolio is the use of experiences (and artifacts from those experiences) to illustrate attributes and skills relative to engineering professional practice. As a result, portfolio construction involves a rhetorical goal of the form, "which of my projects best illustrates this theme I am trying to support in my portfolio." In cases where students have already explored or even indexed their prior experiences in terms of what attributes and skills those experiences illustrate, it could be possible for students to solve this type of rhetorical problem without having to solve the underlying content problem. However, it seems quite possible that this rhetorical problem could trigger students to grapple with content problems of the form, "what is the significance of my experiences in the context of engineering professional practice." The following quotes show evidence of this type of rhetorical problem, and thus evidence of the possibility of this type of content problem.

During the past week I've been thinking about what skills I mentioned in my professional statement and in my artifacts and tried to make *connections* between them. Class A, Week 6 (emphasis added)

I have been picking out different artifacts and *relating them* to the skills my career path requires. The artifacts I chose had to be enough to at least explain how I have the skills needed. Class A, Week 4 (emphasis added)

Other rhetorical problems. Concerning rhetorical problems that were unlikely to induce content problems, a great deal of the comments had to do with students making sense of the portfolio genre (i.e., what are the rules about building a portfolio, what is the best way to do x in a portfolio). The following quotes illustrate these types of problem identification and problem solution.

I am learning what I like and don't like in portfolios, while also generating new ideas for what kinds of information I can have in my portfolio. I am also generating ideas for the style, format, and purpose of my portfolio. Class B, Week 2

I've been judging portfolios basically - looking at examples and finding what I like and dislike. In an attempt to compare and contrast portfolios, it's been interesting to see the dimensions along which I can compare them (e.g., explicitness of purpose, entertainment). Class A Week 2

How information is laid out and how paragraphs are written determines how easy it is to read, how easily someone can scan it. Class B, Week 7

Discussion

In summary, our exploratory analysis of the written process reflections indicated the presence of content problems as well as rhetorical problems, and also of a range of rhetorical problems which had the potential to lead to additional content problems. We also noted a range of issues addressed by these problems – issues of value of experience as preparedness for practice, the absolute and relative importance of concepts and experiences, reconciliation of personality and engineering qualities, and ability to map between skills in the abstract and specific experiences as examples of skills.   Further, the analysis was able to show that portfolio construction activities did bring up issues related to their understanding of their experiences, their conceptions of the discipline, and an understanding of personal identity. However, to more clearly map the issues raised by students to the categories of experience, conceptions, and identity, we need a richer understanding of these categories.

It is interesting to reflect on why we did not find more explicit evidence of content problems. For example, one potential explanation is that we saw a limited number of content problems because students had limited writing expertise and thus had difficulty in moving from rhetorical problems to content problems. Based on our own observations in the classroom and in informal conversations, however, we are not so certain that that is true. Rather, we are withholding judgment until we turn to our other data sources (e.g., informal interviews with students between class sessions and a limited number of verbal protocols collected from students while they were

engaged in working on the portfolios). We believe that such sources of data may be more sensitive to picking up the existence of content problems, particularly for students for whom the rhetorical problems were likely very salient and thus easy to describe (and thus may have precluded them talking about any content problems they were encountering). We believe that such data sources will help us identify, in particular, cases where certain "promising" rhetorical problems became content problems.

Conclusion

In our work, we are exploring the idea that creative construction of a professional engineering portfolio can be a pedagogical intervention that will help the engineering education community support students as they seek to engage their own disciplinary conceptions, interpret their past experiences as professionals and build their identities as engineers. In particular, we believe that portfolio creation can function as knowledge transformational writing in which the rhetorical problems associated with portfolio construction (how to explain this to an audience within this genre) can turn into content problems (what do I really know about this) specifically content problems associated with understanding the general ideas of engineering (conceptions), of experiences, and of self (identity). In this study, we used written process reflections to document the existence of content problem solving as well as rhetorical problem solving, identified some of the content problems that were generated (and also some that may have been generated), and attempted to map those content problems into the three categories of experience, conception, and identity.

This work provides evidence to support the claim that portfolio construction leads to significant forms of knowledge transformation. Because of the exploratory nature of the study, however, this conclusion is not intended to be generalized to all students. Rather, the conclusion is the portfolio construction can lead to these types of outcomes for some students.   At the same time, it is interesting to note that the problems encountered by the students were those encountered by strong students.

We are seeking to strengthen our conclusions through our current work. In that work, we are a) looking to other data sources to see evidence of rhetorical problems becoming content problems, b) exploring the relative timing of rhetorical and content problems—when are the content problems more likely to arise, what can we infer about the conditions under which content problems arise, and c) looking to interviews to gain insight into the actual learning outcomes associated with portfolio construction.

We believe that the significance of this work lies in the need for the engineering education community to seriously grapple with how to support students in developing into effective, enthusiastic, and innovative engineers. Becoming an engineer is a complex undertaking. This work is shedding light on how we might do that, through both the portfolio construction as well as through other mechanisms. This work is also shedding light on challenges that students may face, such as challenges of seeing the relevance of prior experiences on the road to becoming an engineer.

Acknowledgements

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