A Collaborative Process Leading to Adoption of ASCE BOK3 Consistent with ABET

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Matthew Lovell is an Associate Professor in the Civil Engineering Department at Rose-Hulman Institute of Technology, and he currently serves as the Interim Senior Director of Institutional Research, Planning, and Assessment office. He is also serving as the director of the Making Academic Change Happen (MACH) program. He received his Ph.D. from Purdue University, and he holds his PE license in Indiana. Matt is very active with respect to experimentation in the classroom. He greatly enjoys problem-based learning and challenge-based instruction. Matt is the 2018 recipient of the American Concrete Institute's Walter P. Moore, Jr. Faculty Achievement Award. He was awarded Teacher of the Year for the Illinois Indiana section of ASEE in 2017. Also, he was awarded the Daniel V. Terrell Outstanding Paper Award

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Dr. Jennifer Mueller PE P.E., Rose-Hulman Institute of Technology

Jennifer Mueller, PhD, PE, is an Associate Professor in the Department of Civil and Environmental Engineering at Rose-Hulman Institute of Technology. She obtained her BS in Environmental Engineering from Northwestern University, and she earned her MS and PhD in Civil Engineering, with a focus on environmental river mechanics, from Colorado State University. Dr. Mueller's teaching and research areas focus on environmental and water resources engineering, including stream restoration, sustainable design, environmental river mechanics, and stormwater management practices for low-impact development. As graduates of Rose-Hulman typically leave with technical competency, she feels strongly that students need to understand the importance of also developing skills in non-technical areas, including sustainability, ethics, and critical thinking. Additionally, Dr. Mueller aspires to continue to provide meaningful experiential learning opportunities for her students. Through these experiential learning activities and real-life scenarios applied in her courses, students experience the application of technical concepts being taught and non-technical skills for big picture problem solving

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Abstract

The Rose-Hulman Institute of Technology Department of Civil and Environmental Engineering identified the coming release of ASCE BOK3 and the new ABET 1-7 student outcomes as an opportunity to review and revise their program learning outcomes. The program concluded it would be most effective to foster adoption of new outcomes during the 2018-19 academic year, to be followed immediately thereafter by curricular revision to address the new outcomes. All of the faculty members took part in the process, with teams of faculty taking leadership of four to six BOK3 outcomes, identifying their fit with ABET 1-7 and civil engineering-specific program criteria, comparing with institute student outcomes, and ultimately recommending department adoption of outcomes synchronized with BOK3, ABET and the institute requirements. This paper shares the process followed by the department, including our discussions about prioritizing student learning, trust in each other that we could evolve to an effective final outcome, and how we agreed in advance to manage unexpected discoveries or challenges during the process. As a part of this, we formulated and followed a specific process for adoption of BOK3 learning outcomes. During that process, some affective learning outcomes were judged highly appropriate for the specific outcome and thus adopted. The paper deals only with development of the outcomes and a philosophy about creation of criteria for assessing student work, but does not address actual curricular change. Some significant challenges have been encountered in the process, including differences between BOK3, ABET and the institute in outcome wording, level of attainment, and scope of learning, but we were able to account for the differences by prioritizing student learning first while retaining consistency with ABET requirements.

Adoption of the new outcomes is a first stage for planning curricular change during the 2019-20 academic year, when we anticipate the new outcomes to be in effect. We are confident the adopted outcomes, as well as the steps being taken to explore additional affective outcomes, have the potential to significantly improve student learning in our program. We conclude with recommendations for other programs to adopt processes appropriate to their own setting, needs, and goals in order to foster effective changes in their own programs.

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Introduction

The American Society of Civil Engineers 3rd edition of the Civil Engineering Body of Knowledge (ASCE, 2018) will be available in final form in May 2019. Meanwhile, a draft of the Body of Knowledge has been in distribution for review and editing since about mid-2018. The third edition of the ASCE Body of Knowledge, referred to herein as BOK3, features 21 cognitive learning outcomes and seven affective learning outcomes. BOK3 represents a significant revision from the previous edition, which featured 24 learning outcomes, all of which were in the cognitive domain. For 2019, ABET will be conducting engineering accreditation using new student outcomes as well (ABET, 2018). The prior 11 student outcomes (ABET, 2017), lettered and most often referred to as (a)-(k), have been replaced by seven student outcomes, numbered 1-7. The change from the prior to the current ABET outcomes is a significant revision.

The Department of Civil and Environmental Engineering at Rose-Hulman Institute of Technology was an early adopter of the second edition of the ASCE Body of Knowledge (ASCE, 2008). The guidance and specificity in that prior work is an outcome of exceptional scholarship and extensive dialogue among experts about prioritizing civil engineering learning. We have found use of the second edition of the ASCE Body of Knowledge to be a crucial guide in planning learning and continuous improvement, and wish to continue doing so to the direct benefit of our students. BOK3 does not align well with ABET 1-7, nor is it necessarily consistent with ABET program-specific criteria for civil engineering (ABET, 2018). This is not surprising, since ABET guidelines represent minimum expectations for accreditation, while BOK3 is aspirational, setting a high level of expectation for learning. Continuous improvement should be a program's first priority. But successful accreditation is certainly a subset of good continuous improvement for most programs. So programs that wish to adopt BOK3 or any other outcomes to foster strong continuous improvement should not neglect the need to be ABET-accredited. Thus, compatibility between a program's outcomes and ABET should be assured.

Four Competing Outcomes Guidelines

Development of our student outcomes was primarily guided by departmental priorities for student learning and fostering alignment with our program educational objectives. But we had a goal to synchronize our outcomes with (1) ABET 1-7 outcomes, (2) ABET CE-specific curriculum requirements, and (3) ASCE BOK3 outcomes. In addition, our institute also has exceptional student learning outcomes that we wished to include in our program outcomes. This introduces some efficiencies in our continuous improvement processes and aligns us with the rest of the institute. So four different sets of outcomes were considered in setting department priorities for learning.

ASCE BOK3. The ASCE BOK3 is focused on preparing the future civil engineer for entry into the practice of civil engineering at the professional level, which means at the time of licensure (ASCE, 2018). The 21 outcomes consist of four Foundational Outcomes, four Engineering Fundamentals Outcomes, seven Technical Outcomes, and six Professional Outcomes. They are

shown in Table 1. Each of the outcomes recommends levels of learning corresponding to different stages on the learning path to professional licensure, one stage of which is completion of their baccalaureate. The ASCE BOK3 for the baccalaureate level are aspirational because they represent levels of learning that programs should aspire to have their students demonstrate prior to or at the time of graduation. The learning in BOK3 is aspirational not only because of the cognitive learning expectations, but also because some of the outcomes include the affective domain of learning. Table 1 shows which outcomes have only a cognitive component and which have both cognitive and affective components. Affective learning and its assessment in engineering programs is uncommon and perceived to be difficult to teach as well as to assess.

Table 1. ASCE BOK3 Outcomes (ASCE 2018)

Foundational Outcomes		C*	A*
ASCE01	Mathematics	✓	
ASCE02	Natural Sciences	✓	
ASCE03	Social Sciences	✓	
ASCE04	Humanities	✓	
Engineering Fundamentals Outcomes			
ASCE05	Materials Science	✓	
ASCE06	Engineering Mechanics	✓	
ASCE07	Experimental Methods and Data Analysis	✓	
ASCE08	Critical Thinking and Problem Solving	✓	
Technical Outcomes			
ASCE09	Project Management	✓	
ASCE10	Engineering Economics	✓	
ASCE11	Risk and Uncertainty	✓	
ASCE12	Breadth in Civil Engineering Areas	✓	
ASCE13	Design	✓	
ASCE14	Technical Depth	✓	
ASCE15	Sustainability	✓	✓
Professional Outcomes			
ASCE16	Communication	✓	✓
ASCE17	Teamwork and Leadership	✓	✓
ASCE18	Lifelong Learning	✓	✓
ASCE19	Professional Attitudes	✓	✓
ASCE20	Professional Responsibilities	✓	✓
ASCE21	Ethical Responsibilities	✓	✓

*C = Cognitive and A = Affective

ABET 1-7. ABET Criterion 3 Student Outcomes are a standard that indicates minimum expectations for program accreditation. The seven outcomes are shown in Table 2. ABET 1-7 are essential to accreditation processes, but they are minimum standards only and thus leave room for other program student outcomes to assure the highest quality learning and continuous improvement. In addition to ABET 1-7 and not shown in Table 2 is a part of ABET Criterion 5, which specifies "*The curriculum must include…a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.*" (ABET, 2018). Although not classified as an outcome, the implementation of this requirement should be part of a program's curriculum and thus perhaps its outcomes.

Table 2. ABET Criterion 3 Student Outcomes	
1	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3	an ability to communicate effectively with a range of audiences
4	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Other Criteria and Outcomes. Some other learning expectations were also a consideration in the development of our outcomes. Although ABET (ABET 2018) does not require the program specific criteria be assessed like Criterion 3 Outcomes, they should be present in the program and were thus considered in the development of our outcomes. The Curriculum requirements for ABET program-specific criteria for civil engineering were reformatted into list form and are shown in Table 3. The nine requirements for program curriculum in civil engineering have been numbered CE1-CE9 for the convenience of this paper. Like ABET 1-7, the program-specific curriculum requirements for civil engineering are a minimum standard.

Rose-Hulman Institute of Technology also has outcomes that guide the learning in other departments and programs. They are shown in Table 4. These outcomes were developed independent of ABET and ASCE BOK3 and prioritize learning differently from ABET. Even so, these institute outcomes will be assessed by our institute, are required of our students, and have

Table 3. Required Curriculum for ABET Civil Engineering-Specific Criteria (ABET, 2018)	
The curriculum must prepare students to	
CE1	apply knowledge of mathematics through differential equations, calculus-based physics, chemistry, and at least one additional area of basic science;
CE2	apply probability and statistics to address uncertainty;
CE3	analyze & solve problems in at least 4 technical areas appropriate to civil engineering;
CE4	conduct experiments in at least two technical areas of civil engineering and analyze and interpret the resulting data;
CE5	design a system, component, or process in at least two civil engineering contexts;
CE6	include principles of sustainability in design;
CE7	explain basic concepts in project management, business, public policy, and leadership;
CE8	analyze issues in professional ethics; and
CE9	explain the importance of professional licensure.

some alignment with some of BOK3 and ABET. They were thus also taken into consideration in the development of our program outcomes. Table 4 provides the titles of the outcomes along with general expectations of what knowledge and skills students will demonstrate. The outcome numbering of RH1-RH8 are for the purpose of this paper only.

Table 4. Rose-Hulman Institute of Technology Institute Learning Outcomes (April 2019)		
		Rose-Hulman Graduates will be technically competent in their domain and…
RH1	Critical Thinkers	develop evidence-based conclusions through a process of informed evaluation and judgement.
RH2	Creative Problem Solvers	develop and implement a strategy to answer an open-ended question or achieve a desired goal.
RH3	Effective Communicators	communicate effectively with a range of audiences through a variety of media.
RH4	Ethical Professionals	identify ethical and professional responsibilities, behave with integrity and responsibility, and make informed judgements.
RH5	Leaders and Collaborators	motivate and enable a team, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
RH6	Informed Global Citizens	engage with diverse beliefs, cultures, languages, or societies.
RH7	Self-Directed Learners	acquire, apply, and reflect upon new knowledge and skills for personal and professional growth using appropriate learning strategies.
RH8	Civically-Engaged Citizens	partner with a community to create positive change.

Process

We found the process identified below to be effective and appropriate for our program, but other programs may find a different process to be more effective. Although we had a specific series of steps in mind when we began, the process evolved as we discovered what worked well.

1. A department ABET Program Evaluator (PEV) reviewed and prepared a preliminary mapping of all of the outcomes, including mapping of previous outcomes to new BOK3 outcomes. This information was presented in a faculty meeting, and followed by a dialogue about how to proceed with development of outcomes using ASCE BOK3. At this time, the department also discussed whether other outcomes could be needed, and added "Service" to our list.
2. Faculty member teams selected BOK3 outcome(s) to draft (usually identified based on experience with previous outcomes, but sometimes due to individual interest). Four different faculty member teams were formed, so each team selected 4-6 of the proposed outcomes.
3. The faculty teams identified elements of ABET 1-7 and ABET CE-specific criteria that seemed to map to the outcome they were drafting. The faculty teams then crafted revisions to the BOK3 outcomes that accounted for ABET 1-7 and CE-specific requirements.
4. The faculty teams presented their revised outcomes to the department over a series of department meetings. These were discussed by the department, outcome by outcome, so that a single 1-hour department meeting might only address one or two proposed outcomes. As these meetings progressed, the department as a faculty body was able to iteratively
    a. Identify redundancies to eliminate from proposed outcomes,
    b. Clarify common terminology for all faculty teams to apply across outcomes,
    c. Identify ill-defined concepts and develop common definitions for these concepts that were more clearly defined,
    d. Develop a philosophy for use of multiple criteria under a single outcome to address challenges combining outcomes between the four different outcome types,
    e. Prioritize departmental priorities about learning, including the addition, combination and deletion of some outcomes.
5. We compiled a single summary of all outcomes and subjected the combined outcomes list to a common review. In this final step, we examined the outcomes one more time for redundancy, ill-defined terms left over from prior editing, and inclusion of important aspects of ABET 1-7. This final step synchronized our outcomes. The resulting outcomes are shown in Table 5.

Step 4 was a tedious step in the process and required patience. Some examples of the discoveries and decisions made in this step are shared below. In retrospect, the faculty recognized this step was more than a creation of outcomes, as it built a common understanding of the outcomes and helped the department form a more uniform approach to writing outcomes, criteria, and rubrics for assessment. We believe this will foster better assessment and improvement processes later.

Near the conclusion of this process, the faculty members spent considerable time discussing ABET 1-7. Criterion 3 states "Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program." (ABET 2018). Those programs that wish to be accredited must assess learning to assure that ABET's Student Outcomes 1-7 are being attained. We understand that many programs are interpreting this statement to mean that ABET 1-7 must be adopted word-for-word. However, Criterion 3 also requires that "The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering." (ABET 2018) We concluded we could most effectively support our program educational objectives and prepare our students to enter the practice of engineering with the outcomes we have adopted, and not ABET 1-7 word-for-word. We thus decided to assure attainment of ABET 1-7 through the use of specific criteria under our student outcomes.

Table 5. Student Outcomes Developed by Rose-Hulman Institute of Technology Department of Civil and Environmental Engineering	
1	**Mathematics:** Apply mathematics, including differential equations and numerical methods, to solve engineering problems.
2	**Science:** Apply principles of natural science to solve engineering problems.
3	**Social Sciences and Humanities:** Apply concepts and principles developed from humanities and social sciences to inform engineering design.
4	**Materials Science:** Apply concepts and principles of materials science to solve civil engineering problems.
5	**Engineering Mechanics:** Apply concepts and principles of solid and fluid mechanics to solve engineering problems.
6	**Experimental Methods and Data Analysis:** Develop and conduct civil engineering experiments in at least two technical areas, analyze and interpret experimental data, and use engineering judgement to draw conclusions.
7	**Critical Thinking and Problem Solving:** Use a critical thinking process to formulate an effective solution to a complex civil engineering problem.
8	**Project Management:** Apply concepts and principles of project management in the practice of civil engineering.
9	**Engineering Economics:** Apply engineering economics concepts and principles to make engineering decisions.
10	**Risk and Uncertainty:** Apply concepts and principles of probability and statistics to address uncertainty and risk relevant to civil engineering.
11	**Breadth in Civil Engineering Areas:** Apply concepts and principles to solve problems in at least four technical areas appropriate to civil engineering.
12	**Design:** Apply an engineering design process to complex engineering problems in more than one civil engineering technical area.
13	**Technical Depth:** Apply concepts and principles to solve complex engineering problems.
14	**Sustainability:** Apply principles of sustainability in the solution of civil engineering problems.
15	**Communication:** Prepare and present technical content to both specialized and general audiences in an effective manner within verbal, written, and graphical formats.
16	**Leadership:** Apply leadership concepts and principles to direct the efforts of a small group.
17	**Teamwork:** Function effectively as a member of a team.
18	**Lifelong Learning:** Acquire and apply new knowledge as needed, using appropriate learning strategies.
19	**Professional Attitudes:** Practice professional attitudes relevant to the practice of engineering.
20	**Professional Responsibilities:** Explain professional expectations relevant to the practice of civil engineering.
21	**Ethical Responsibilities:** Analyze ethical dilemmas involving conflicting ethical interests to recommend and justify a course of action.
22	**Service:** Demonstrate a commitment to service through the practice of civil engineering.

Table 6 shows how our adopted student outcomes correlate to ABET and Institute Learning Outcomes. We are writing specific criteria for those student outcomes correlated to ABET requirements to assure compliance. We have adopted a department policy to not allow revision of outcome criteria without preparation of an accreditation impact statement and department approval of revisions. The correlation of institute learning outcomes to department student outcomes is appropriate since we are a unit of the institute, and also because they will allow us to utilize institute resources in the assessment of those outcomes.

Table 6. Correlation of RH CE Student Outcomes to ABET and Institute Requirements

	RHIT Civil Engineering Student Outcomes	Contain Specific Criteria for ABET Criterion 3 (1-7) or Criterion 5	Address ABET CE-Specific Curriculum Requirements	Include RH Institute Learning Outcomes
1	Mathematics		CE1	
2	Science		CE1	
3	Social Sciences and Humanities			
4	Materials Science			
5	Engineering Mechanics			
6	Experimental Methods and Data Analysis	Cr3(6)	CE4	
7	Critical Thinking and Problem Solving			RH1, RH2
8	Project Management		CE7	
9	Engineering Economics		CE7	
10	Risk and Uncertainty		CE2	
11	Breadth in Civil Engineering Areas		CE3, CE8	
12	Design	Cr3(1), Cr5	CE5	
13	Technical Depth			
14	Sustainability	Cr3(2)	CE6	
15	Communication	Cr3(3)		RH3
16	Leadership	Cr3(5)	CE7	RH5
17	Teamwork	Cr3(5)		RH5
18	Lifelong Learning	Cr3(7)		RH7
19	Professional Attitudes			RH6
20	Professional Responsibilities	Cr3(4)	CE9	
21	Ethical Responsibilities	Cr3(4)	CE8	RH4
22	Service			RH8

Discoveries and Insights

It was common from one meeting to the next to identify features of one draft outcome that led to discussions by the faculty affecting the writing of other outcomes. Not all of these can be shared within the scope of this paper, but a few particularly significant discoveries and insights are provided below.

Time Commitment to the Process. We held about 12 one-hour department meetings as well as two 3-1/2 hour in-depth meetings to provide common discussion time for this work, resulting in about 20 hours of department meeting time. But considerable time was spent by faculty members outside of those meetings. Faculty time devoted by each faculty member to this process outside of department meetings is estimated to be on the order of the 15-20 hours, for a total of 35-40 hours by each of the faculty members over the course of about 6 months. We consider this a minor contribution to the future success of our students.

"Concepts and principles". ASCE BOK3 often uses the phrase "concepts and principles." The regular use of this phrase prompted discussion about the nature of concepts, principles, and how they differ. We came to an agreement on the definitions of the two terms and subsequently removed one or the other term from some of the final outcome statements. The definitions of concept and principle will be used to guide the preparation of rubrics for assessment as well as the development of learning in the curriculum.

"Engineering" versus "civil engineering". ASCE BOK3 often specifies a "civil engineering" frame of reference for outcomes. The department agreed there are some outcomes for which the term civil engineering should be used, such as for the solution of complex problems, as well as for learning we felt should be civil-engineering specific. This included learning outcome areas such as materials and experiments. The department also agreed there are times in which the solution to problems that are not civil engineering-specific could be a civil engineer's responsibility. We concluded engineering problem-solving outside civil engineering could be beneficial learning, so "civil" was removed from some ASCE BOK3 outcomes to permit this opportunity for broader learning.

Leadership and Teamwork. Being an effective team member does not require leadership. In fact, the most effective teams typically have a single leader setting the vision and motivating the team. We want our students to recognize that being an effective team member does not require them to lead. We want each of our students to demonstrate leadership concepts and principles, but we also want them to understand that it is not necessary or appropriate to lead all the time. Therefore, we believe it is important to create two separate outcomes: Leadership and Teamwork. In addition, we place great emphasis on action when it comes to leadership and teamwork. Rather than have outcomes in the cognitive domain about leading or being a team member in theoretical contexts, we adopted only outcomes in the affective domain where students must demonstrate leadership and effective teamwork.

Humanities and Social Sciences. Social sciences focus on the study of society and the relationships between individuals within society. Humanities deal with heritage and the question of what makes us human. The concepts and principles from both fields weave together to guide us in developing

designs that are contextually appropriate. Creating designs that are informed by only social sciences or only humanities will be less effective than those informed by both. We thus adopted an outcome that combines both social sciences and humanities to inform engineering design.

Use of Criteria. In some cases, the department preferred wording similar to that provided by ASCE BOK3 as compared to wording used in ABET 1-7 or ABET Civil Engineering-Specific criteria. In those cases, the department adopted a student outcome statement consistent with the desired student learning, but also drafted criteria to be applied under that student outcome to assure that the desired learning with respect to ABET and BOK3 requirements is present in the program. We also have revised department policy to increase department control of revisions to the criteria. Going forward and as already noted, revision of outcome criteria will require preparation of an accreditation impact statement and department approval. The intent of this final requirement is to minimize the potential for the situation to change in the future such that ABET Criterion 3, 5 or CE-specific program criteria may not be satisfied.

Recommendations

We were able to revise our student outcomes for alignment with ASCE BOK3 and ABET 1-7 while also taking into consideration other outcomes guidelines significant to our curriculum. This can be duplicated by other programs, although the size and nature of the program will affect the details. Following is some advice about making use of this process.

- A large program would find it difficult to involve all of the faculty members. Our faculty members were able to meet every one to two weeks, and all were engaged in our curriculum development and well-informed about continuous improvement and assessment processes through experience and independent study. Larger programs should select a subset of faculty members with similar experience and commitment that is representative of the faculty body as a whole.
- The faculty should agree to not always agree (in most cases). It is highly unlikely that all faculty members will agree on all outcomes. However, all faculty members do need to agree to support the final outcomes at the start of the process. In fact, we found the development of outcomes was as much about development of a common approach to assessment as it was about the specific wording or focus of the outcome. Differences of opinion should be appreciated and respected. Faculty members should help each other mediate those differences and maintain focus on student learning. As a result, workable outcomes will be achieved and the faculty will have a more uniform understanding of department priorities in learning.
- Focus must be maintained on student learning. This is a uniform goal of well-meaning faculty members. While there will often be different opinions on depth versus breadth and the amount of specialization, the use of the ASCE BOK3 framework as a starting point will help with management of those differences.
- Development of outcomes should not be guided by what is in the existing curriculum. Revision of the ASCE Body of Knowledge supports the idea that existing curricula may no longer be best. Curricula should generally be pushed aside while developing outcomes.
- Programs must remember BOK3 is a suggested model for learning. Different programs have different priorities, strengths and settings. The unique characteristics of each program should not be lost as a result of uniform adoption of ASCE BOK3 without revision.

Summary

Adoption of the new outcomes is a first stage for establishing curricular change during the 2019-20 academic year. We are confident the adopted outcomes, including the development of affective learning outcomes, have the potential to significantly improve student learning in our program. We encourage other programs to consider similar processes to assure development of student outcomes that can directly impact the quality of learning.

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