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Research

How Undergraduate Science Students Use Learning Objectives to Study †

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Learning objectives communicate the knowledge and skills that instructors intend for students to acquire in a course. Student performance can be enhanced when learning objectives align with instruction and assessment. We understand how instructors should use learning objectives, but we know less about how students should use them. We investigated students' use and perceptions of learning objectives in an undergraduate science course at a public research university. In this exploratory study, students (*n* = 185) completed two open-ended assignments regarding learning objectives and we analyzed the content of their answers. We found that students used learning objectives in ways that reflected the recommendations of past and present instructors, suggesting that students are receptive to instruction on how to use learning objectives. Students generally found learning objectives to be useful because the objectives helped them to narrow their focus and organize their studying, suggesting that students may need additional help from instructors in order to self-direct their learning. Students who chose not to use learning objectives often found other resources, such as case studies covered in class, to be more helpful for their learning. Some of these students recognized that the concepts included in case studies and learning objectives overlapped, pointing to a benefit of alignment between instructional activities and learning objectives. These qualitative results provide the data necessary for designing a quantitative instrument to test the extent to which students' use of learning objectives affects their performance.

INTRODUCTION

Many students come to college with a limited set of study strategies, which hinders their ability to be successful in undergraduate science courses in which they are expected to direct their own learning (1–3). When faculty provide learning objectives, students can use these tools to help guide their own studying. Learning objectives are statements that communicate the knowledge and skills that instructors intend for students to acquire (4, 5). While learning objectives have the potential to enhance student knowledge and skills, they could be more effective if faculty provided instructions to students on how to use them. To do this in an evidence-based way, researchers first need to explore how students currently use learning objectives and what instructions, if any, students receive in their courses about how to use them.

Learning objectives state what students should know and be able to do following a period of instruction (6). Unlike a list of topics, learning objectives usually describe actions students can take if they have successfully learned something. For example, the learning objective "predict the effect of mutations in the carbonic anhydrase protein on its function and blood pH" is distinct from the topic "carbonic anhydrase." Learning objectives also differ slightly from learning *outcomes*. Learning objectives can be described as the *anticipated* knowledge and skills that students *should* obtain, while learning outcomes can be described as the *observable* knowledge and skills that students *have* obtained. Learning outcomes state what students will achieve, whereas learning objectives state what the instructors intend for students to achieve (5).

The best practices for writing learning objectives have been outlined for instructors (7, 8). Learning objectives should describe measurable goals that can be observed if met (4). These goals should focus on specific student actions or behaviors that can demonstrate success (4, 7). Instructors should use Bloom's Taxonomy to create learning objectives that go beyond "lower-order" cognitive skills such as knowledge and comprehension, and instead focus on "higher-order" cognitive skills such as analysis and evaluation (9–11). For example, students can be encouraged to *differentiate* between related concepts or *appraise* claims

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made from data rather than just *describe* a pathway or *explain* an idea (8). Once written, learning objectives should be used by instructors as a framework to organize course assessments and instructional activities (12).

Aligning learning objectives with instructional activities and course assessments can result in significant learning experiences (Fig. 1) (13). Alignment can be achieved through "backward design" in which instructors first write learning objectives, then determine how they will assess whether students have met the objectives, and lastly create instructional activities that address the objectives (14, 15). This process helps ensure that class time is used effectively (13). Additionally, by sharing learning objectives, instructors can make their intentions transparent so that students know what is expected of them (16).

Some studies have provided insight into undergraduate students' perceptions of learning objectives. Students in an upper-division microbiology course valued learning objectives for highlighting what they needed to know (17). Undergraduates studying biology, English, and medicine in the United Kingdom found learning objectives helpful, but they were unsure about the level of detail required to satisfy each objective (18). While these studies provide a sense of how students view learning objectives, less is known about how students are actually using learning objectives and what instructors are telling students about how to use them.

Given the potential for learning objectives to enhance performance, instructors should try to help students use them effectively. As an initial step toward assisting students, we asked three main research questions in this exploratory study:

- What instructions have undergraduate science students been given about using learning objectives?
- How do students use learning objectives to study?
- Why do students find learning objectives helpful?

In addition to these main questions, we also asked three related questions:

- How do students perceive the alignment between learning objectives and summative assessment?
- Why don't students use learning objectives to study?
- What do students think the purpose of learning objectives is?

The data from our exploratory study provide insights into how students perceive and use learning objectives in an upper-division science course without instructional intervention. These qualitative results provide data needed for designing a quantitative instrument to measure students' use and perception of learning objectives (19, 20). A quantitative instrument would allow researchers to determine the extent to which students' use and perception of learning objectives affects their performance in science courses.

METHODS

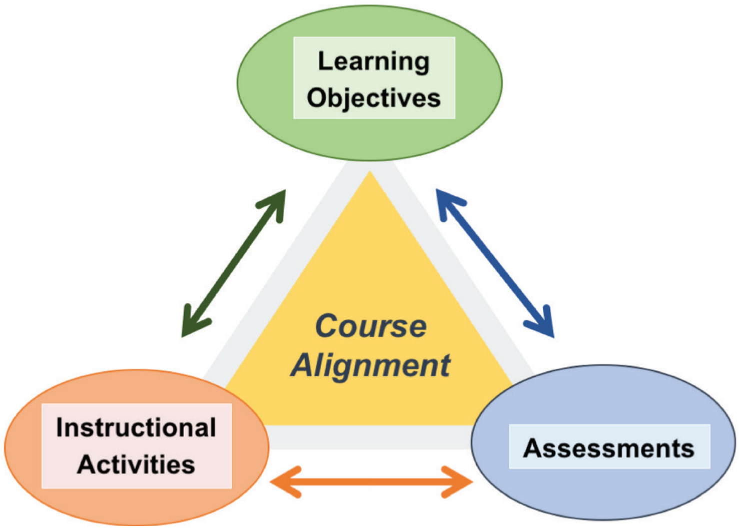
Participants and context

Participants (n = 185) were undergraduates taking a 300-level science course at a public doctoral university. Introduction to Biochemistry and Molecular Biology (BCMB3100) is a lecture-only course focused on topics such as enzymology, bioenergetics, and metabolism. BCMB3100 serves 16 majors, such as biology, environmental chemistry, and nutrition science, and many of the students who enroll in the course plan to pursue careers in the health sciences. Students generally take the course during their sophomore or junior year. We collected data from a BCMB3100 section co-taught by two instructors who teach exclusively through the use of case studies (21, 22). In this approach, students work with peers on real-world problems that require them to analyze information and apply it to new situations (23). Both instructors provided learning objectives to students at the start of each of the four units in the course by posting a file in an online learning management system. For each day of the unit, four to seven learning objectives were given. Using backward design, the instructors then wrote formative assessments (quizzes on textbook readings, clicker questions, and case studies) and summative assessments (exams) that aligned with their learning objectives (Fig. 1).

The instructors addressed learning objectives in their syllabus as follows: "*Focus on the learning objectives.* The exams will assess your accomplishment of the learning objectives. Use the learning objectives as a guide for what to focus on when you are completing assignments and studying for exams." They also repeated these instructions in class on the first day. Because this was a descriptive qualitative study to learn how students currently use learning objectives without intervention, we did not observe or record the way instructors talked about learning objectives in class.

Data collection

Students completed two homework assignments regarding their use of learning objectives after the first and second exams in the course (see Appendices 1 and 2). The assignments were distributed on paper in class and collected from students a week later in class. The first assignment (LOA1) was given after Exam 1 and focused on undergraduate students' perceptions and use of learning objectives. LOA1 had three questions for all students (n = 185), five questions that were specific to students who used the learning objectives (n = 133), and three questions that were specific to students who did not use the learning objectives (n = 52). The second assignment (LOA2) was given after Exam 2 and was completed by 157 students. LOA2 focused on instructions students received about using learning objectives and asked for their advice to other students on using learning objectives. Students earned three extra-credit points (the equivalent of two exam questions)



Learning Objective	Explain what it means to be a ketogenic vs. glucogenic amino acid. Know what a ketone body is and how it can be used as fuel.
Instructional Activity	Case study on amino acid metabolism
Assessment	Can a ketogenic amino acid be used to synthesize glucose? Your answer should include (1) a claim – yes or no; (2) a reasoning that justifies your answer and (3) a description of what it means to be a ketogenic vs. glucogenic amino acid.

FIGURE 1. Alignment of course components. Students can benefit when the learning objectives, instructional activities, and assessments in their courses align. The examples of each component given here are from an introductory biochemistry course.

for each assignment. Only students who were 18 years or older and gave informed consent were included in our study. The University of Georgia Institutional Review Board approved this research (STUDY00001740).

Qualitative data analysis

First, we sought to identify pieces of data related to our research questions and label these data with meaningful codes. We began by reading all of the data with an openness to the participants' ideas for the purpose of understanding the scope of the data before coding it (24). Next, we used content analysis to develop codes that could represent the data that corresponded to our research questions. We tested these potential codes on a subset of the data (approximately 25% of the assignments) and modified the codes as needed. We developed a codebook through a repetitive process of testing the codes on additional subsets of data and revising the codebook as needed. Using our fully revised codebook, we coded the entire data set in 20% increments, meeting to discuss our codes after each increment was finished. We repeated this process until all the data were analyzed. All three authors (BO, BM, and JDS) coded all 185 first assignments. Two authors (BO and BM) coded all 157 second assignments, with the remaining author (JDS) checking a subset of the second assignment data using the fully revised codebook. We coded to consensus rather than using interrater reliability because we did not want to overlook nuanced details (25–27) (see also Appendix 3).

Second, we sought to identify categories of codes that could lead us to possible themes in the data. We used pattern coding to group related codes that corresponded to each of our research questions (24). Two authors (BM and JDS) applied pattern coding methods to the codes corresponding to all research questions. They analyzed the codes individually and then met to discuss their code groups and resulting categories. After revisions based on discussion, the remaining author (BO) checked the revised code groups and categories to ensure they aligned with her analysis of the LOA1 and LOA2 data. We used consensus coding to ensure rigor (see also Appendix 3).

RESULTS

What instructions have undergraduate science students been given about using learning objectives?

Students in this study reported the instructions they had been given in college about how to use learning objectives in *any* of their courses. Several students wrote that they did not recall receiving informal or formal instruction on how to use learning objectives, although some of these students had a sense of how to use learning objectives. This idea is exemplified by the following statement: *"I have never really received any formal instructions but it is implied that we should be able to fully understand and answer questions on the learning objectives."*

Some students wrote about receiving detailed instructions on how to use learning objectives in the introductory biochemistry course where our data collection took place. A student wrote: "*We have been told to read over the learning objectives before beginning to study. Then after reviewing our notes, we are to go back and talk ourselves through each learning objective or type up a response for each learning objective.*"

Students reported receiving instructions on learning objectives that fit into four major categories. They were told to 1) complete them (38.2%); 2) use them to inform studying (33.8%); 3) use them passively, e.g., just "look over" the learning objectives (9.6%); and 4) use them to self-assess understanding (6.4%).

Most commonly, instructors told students to complete the learning objectives (38.2%), either by answering them or understanding them. Many students (31.8%) reported being told to answer the learning objectives as if they were questions. Other students wrote that instructors told them to simply understand (4.5%) or explain (1.9%) the learning objectives.

Many students (33.8%) reported being instructed to use learning objectives to inform their studying. Students reported being told to use the learning objectives as a study guide (14.7%), to organize studying (5.1%), to narrow focus (8.3%), and to connect resources (5.7%). In contrast, some students (9.6%) reported being told to use the learning objectives in a passive way. For example, students reported being told to just "look over" the learning objectives.

Finally, a few students (6.4%) reported that they were instructed to use learning objectives to self-assess their knowledge. They wrote about using the learning objectives to monitor understanding and to test themselves. For example, one student wrote that they were told to "*use the learning objectives as a guide to gauge the level of understanding.*"

How do students use learning objectives to study?

Students' use of learning objectives in preparation for the first exam fit into four major categories (Table 1):

1. As questions to answer (47.4%)
2. As a resource for studying (24.1%)
3. As a self-assessment tool (14.3%)
4. Passive use (13.5%)

In general, students' use of learning objectives mirrored the recommendations they reported receiving. For example, the most common way students reported using learning objectives (47.4%) was to answer them as if they were questions. This idea is exemplified by the following statement: *"I compiled [the learning objectives] all into a Word doc one week prior to the exam and answered all the learning objectives."*

Many students (24.1%) used the learning objectives as a resource when studying. They reported using them as a study guide, as a checklist for topics to cover, and as a way to compare information from different resources. For example, one student explained that learning objectives helped them connect the concepts in the case studies and the lecture slides.

Some students (14.3%) used the learning objectives to self-assess their knowledge of the concepts. They wrote about monitoring understanding and testing themselves on the material. For example, a student wrote about using the learning objectives to identify areas of confusion so they could allocate their time accordingly: *"I used the learning objectives to help determine what areas I should study and then to quiz myself on the information to see what I need to spend more time on."*

Some students (13.5%) reported using the learning objectives in a passive way. These students used phrases such as "went over," which suggested that they didn't use the learning objectives actively. For example, one student wrote, "*I went over each [learning objective] in my head.*"

How do students perceive the alignment between the learning objectives and summative assessment?

If learning objectives do not align with assessment, students will be less likely to find them helpful (11). Nearly all of the students who used learning objectives felt they aligned very well (81.2%) or fairly well (15.0%) with questions on the first exam (Table 2). Some of the students who reported

TABLE 1
How did students use learning objectives to study?

Category	How Students Reported Using Learning Objectives (LO) (*n* = 133)	Number of Students	Percent of Students
As questions to answer	Answered LO as if they were questions	63	47.4%
As a resource for studying	Compared LO with other course resources	15	11.3%
	Used LO as a study guide	14	10.5%
	Used LO as a checklist	3	2.3%
To self-assess understanding	Monitored understanding with LO	6	4.5%
	Self-tested with LO	4	3.0%
	Made sure they could do each LO	9	6.8%
Passive use	Looked over LO	18	13.5%
—	Other use of LO (not listed above)	1	0.8%

One hundred thirty-three students reported that they used learning objectives to study for the first exam. These students were asked how they used learning objectives using an open-ended question, and their responses were coded using content analysis. In cases where more than one use was reported, the use most emphasized by the participant was recorded. The number and percentage of students who gave each response are shown (*n* = 133).

TABLE 2.
How well did the learning objectives align with the exam?

How Well Students Felt Learning Objectives (LO) Aligned with Exam Questions (n = 133)	Number of Students	Percent of Students
Very well	108	81.2%
Fairly well	20	15.0%
Not well	0	0%
Other (did not answer this question)	5	3.8%

The 133 students who used learning objectives to study for the first exam were asked how well the learning objectives aligned with the exam questions. The number and percentage of students who reported each level of alignment are shown (n = 133).

that the learning objectives aligned "fairly well" noted that they did not realize they were responsible for being able to apply the learning objectives. Of the remaining students who used the learning objectives (3.8%), four students did not answer this question and one student could not recall whether or not the learning objectives aligned with the exam. None of the students who used learning objectives reported that the learning objectives did not align with the exam questions.

Why do students find learning objectives helpful?

Students who used the learning objectives to prepare for the first exam reported that these tools helped them to do the following:

1. Narrow down the information (57.1%)
2. Organize their studying (23.3%)
3. Communicate information (5.3%)
4. Monitor their understanding (4.5%)
5. Forced them to study (1.5%)

More than half of the students (57.1%) reported that that learning objectives helped them narrow down the information they needed to study. There were two areas in which students appreciated help narrowing their focus: 1) for topics to be learned in the course and 2) for topics to be studied for exams. One student explained how the learning objectives helped focus their studying: *"The book is dense and the cases are detailed. The learning objectives serve to direct my studying so as not to waste time. It helped emphasize what's important."*

Other students reported that learning objectives provided organization for studying (23.3%). Within this category, students also wrote about learning objectives serving as study guides and providing the big picture. This idea is exemplified by the following statement: "*[Learning objectives] helped me work from general theme to important details. Usually learning for this class works from details to general theme. This reversal was helpful."* Not only did students perceive learning objectives as helpful for organizing their studying, they also perceived this help with organization as the purpose of learning objectives (Appendix 3).

Some students (5.3%) reported that learning objectives served as a means of communication from their instructor. In particular, the students viewed learning objectives as a way their instructors could share their expectations. For example, a student wrote, "*[Learning objectives] told me what I was expected to know.*" The opportunity for professors to communicate with students was also perceived by students as an important purpose of learning objectives (Appendix 3).

Some students (4.5%) explained that the learning objectives allowed them to monitor their understanding of the concepts. A student explained, *"[Learning objectives] helped me identify all the gaps in my knowledge from the case studies."* Finally, two students in our study (1.5%) described the helpfulness of learning objectives in a unique way. They suggested that learning objectives forced or pushed them to study. Both students wrote about learning objectives as a strong imperative. This is exemplified by the following statement: "*[Learning objectives] forced me to study. Being able to understand them meant I finally understood the material."*

Why don't students use learning objectives to study?

Several students (28.1%) opted not to use learning objectives to prepare for the first exam. Their reasons fit into four categories (Table 3):

1. Learning objectives were not necessary (42.3%)
2. Learning objectives were not a priority (28.8%)
3. Learning objectives were not helpful (13.5%)
4. Students were not aware of learning objectives (15.4%)

Many of the 42.3% of students who did not deem the learning objectives necessary wrote about viewing the case studies as more important than the learning objectives. For some of these students, alignment of case studies and learning objectives with the exams made these two tools redundant. A student explained: *"Based on the old exam, it looked like the questions came directly from the case studies and the case studies emphasized the learning objectives."*

Some students (9.6%) reported that the learning objectives were not necessary because they felt well prepared for the exam without using them. One student wrote: *"I thought*

TABLE 3.
Why didn't students use the learning objectives to study?

Categories	Reasons Why Students Didn't Use Learning Objectives (LO) (n = 52)	Number of Students	Percent of Students
LO were not necessary	Used case studies instead of LO	13	25%
	Was prepared without using LO	5	9.6%
	Case studies incorporate LO	4	7.7%
LO were not a priority	Ran out of time to use LO	15	28.8%
LO were not helpful	LO were not helpful	7	13.5%
Not aware of LO	Did not know about/remember LO	8	15.4%

Fifty-two students reported that they did not use learning objectives to study for the first exam. These students were asked why they did not use learning objectives using an open-ended question, and their answers were coded using content analysis. The number and percentage of students who gave each response are shown (n = 52).

I had a comprehensive understanding of the material that was presented and I thought I had enough on my plate studying the way I did." Notably, this student reported that they would use the learning objectives for future exams because they had done poorly when studying without learning objectives.

Many students (28.8%) did not make the use of learning objectives a high priority, and thus they did not have time to use them. Similarly, some students (13.5%) chose not to use the learning objectives because they did not perceive them to be helpful. In a few cases, this perception was because students felt that the learning objectives were too general. Lastly, some students (15.4%) admitted to not being aware of the learning objectives' existence.

Many of the students who did not use learning objectives for the first exam used them for the second exam (n = 16, 30.8%). These students reported using learning objectives to guide their studying and to test themselves on concepts. Only one of these 16 students reported that they wished they had not used learning objectives for the second exam, because of their performance on that exam. Furthermore, only some of the students who used learning objectives for the first exam chose not use them again for the second exam (n = 11, 8.3%). Their reasons varied, from lack of time to prioritizing the case studies. Interestingly, four of these 11 students reported that they wished they had continued using learning objectives for the second exam. One student wrote, *"I would definitely study the learning objectives (in the future). I didn't for the second exam because I got lazy and procrastinated too much and it was evident in my grade."*

DISCUSSION

Findings and explanations

Recommendations exist for how instructors should write and use learning objectives (4, 7, 8), but less is known about how students in undergraduate science courses should use learning objectives (17). Students in our study used learning objectives in ways that reflected what their past and present instructors had suggested. For example, answering the learning objectives as if they were questions was the most common use reported by students, and it was also the most common instructor recommendation students reported. This finding suggests that students are receptive to instruction regarding the use of learning objectives. Students' receptiveness might be due to the fact that they generally did not use learning objectives to study in high school, making them more open to instruction on how to use this tool.

Most students in our study explained that learning objectives were useful because they helped them narrow their focus and organize their studying. This finding suggests that students at this level are still uncertain about what is important to learn from a science course like introductory biochemistry (17). As students move from a novice-like state to an expert-like state (28), they may need additional help identifying key concepts. One way instructors can help students do this is by sharing their learning objectives. Students can then use learning objectives to help self-direct their studying (29). Because studying is a goal-directed behavior (30, 31), providing students with goals for what they should know and be able to do in the form of learning objectives can help ensure that their studying is more effective.

The data from our exploratory study provide a critical first step toward understanding the extent to which using learning objectives might affect student performance in a science course. In order to test a possible relationship, we need to collect data from numerous classrooms to control for the variability that exists across students, instructors, and instructional contexts. Our results provide categories on students' use and perception of learning objectives that can be used to create a Likert-style instrument for surveying science students in a variety of settings (19). This approach would allow us to make conclusions about the effects of students' use and perception of learning objectives on their performance in science courses. A future quantitative study would also allow us to determine the generalizability of the qualitative findings of this paper (20, 32).

Limitations

We gained rich descriptions of students' use and perceptions of learning objectives through two written assignments; however, there are limitations to self-report data. We attempted to address these limitations in our study. For example, as researchers we cannot know for certain whether or not students did what they reported on their assignments. We tried to decrease social desirability bias—the desire to provide favorable responses (33)—by giving students full credit for their participation in the study, regardless of their answers. We also had students submit the assignments directly to us as researchers rather than to their instructors. Additionally, written data do not allow researchers the opportunity to clarify the meaning of participants' words (34). We analyzed the data as a diverse team of faculty and student researchers so that we could carefully consider the interpretation of participants' written statements. Finally, it should be noted that this study was done at one institution, in one course, which was taught in a case-study format. The results might have been different if the research had been conducted at a different institution or in a different course with a different format. Exploring students' use and views of learning objectives in diverse settings could provide additional insights.

Implications for teaching

Our data suggest some ways instructors can help students use learning objectives. First, we recommend giving students explicit instructions on how to use learning objectives. For example, an instructor can demonstrate how to turn a few learning objectives into questions and how to go about answering them, and then ask students to do the same in class or as an assignment. Modeling these simple steps can be important for facilitating the use of learning objectives (35, 36). Introductory students are often willing to try new approaches to learning, but they may not carry them out if they don't know how to (34). Second, we recommend that instructors encourage students to use learning objectives for self-assessment. Some students in our study reported using learning objectives to test themselves or to monitor their understanding. When students identify what they do and do not understand, this can positively impact learning and memory (37, 38); however, some students may avoid identifying areas of confusion because this causes them stress (39). These students could benefit from an instructor emphasizing the value of using learning objectives to self-assess their learning. Third, if instructors want students to use learning objectives, these should be aligned with other parts of the course, including class activities and exams (13). In our study, over 70% of students used the learning objectives for Exam 1, and nearly all of these students said the learning objectives aligned with the exam. For Exam 2, nearly 75% of the students reported using the learning objectives to study. Thus, instructors should aim to align the objectives they have for their students with the way they assess whether or not students have met those objectives.

By following the suggestions derived from our data, instructors may be able to help students use learning objectives more effectively. In turn, more effective use of learning objectives could improve student learning and performance.

SUPPLEMENTAL MATERIALS

Appendix 1: Learning objectives assignment 1 (LOA1)
Appendix 2: Learning objectives assignment 2 (LOA2)
Appendix 3: Supplemental methods and supplemental results

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