What challenges do students face in introductory STEM courses, and how can instructors help?

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ABSTRACT: We focus here on the role of belonging in introductory STEM, especially as it may impact student performance and intention to remain in the discipline. Specifically, doubts about belonging in the classroom are often shouldered disproportionately by students from marginalized groups, which can lead to underperformance and may explain the attrition of, for example, women in the STEM pathway [2]. To complement ongoing research on belonging [4], and because belonging is linked to how students perceive and manage academic challenges, we conducted a study on self-reported challenges, along with coping strategies, in introductory-STEM students at the University of Bergen. Specifically, we surveyed students in an introductory computer science course (n=176), taken by all undergraduates at the Faculty of Mathematics and Natural Sciences, about their anticipated challenges, asking them to respond to a single open-ended question: *Today, we'd like each of you to reflect on some of the concerns you may have about taking this course. What do you think will be difficult or challenging for you?*

We used inductive coding to categorize student responses and group these categories into broader themes. For example, a student reporting that *I worry that I will not understand anything* was categorized as "comprehension". Another quote *Worried about coding badly and not keeping up with the rest of the class* was categorized as "afraid of falling behind." Our findings are informative and, in a sense, encouraging, as many of the student concerns can be mitigated by instructional choices. We conclude with an example of how instructor behaviours can alleviate some common student concerns in introductory science courses.

1 INTRODUCTION

As teachers in higher education we want to provide an equitable learning environment that results in low attrition, high performance and course satisfaction for all students. Introductory courses especially are faced with the task of presenting the discipline and helping students decide whether to continue in that field. Because prior work in disparate fields has documented meaningful relationships between student affect (e.g., self-efficacy, sense of belonging, test anxiety) and outcomes (e.g., performance, retention), and because student affect can be malleable (and subject to instructional choices), further exploration is warranted. Specifically, we focus here on sense of belonging in introductory computer science.

Student sense of belonging has long been a topic of education research and how it affects student learning in terms of attrition, performance, engagement and self-efficacy. In the field of computer science a students sense of belonging has been linked to a students *perception* of ones ability, possibly more so than actual *performance* [7], echoing findings from fields such as math [3], engineering [8], and science in general [5]. Because belonging involves how students interpret and manage challenges, recent belonging studies have focused on student perceptions of challenges in their courses. As part of an ongoing replication study of [4] in a Norwegian context, students in a first-semester computer science course wrote down their anticipated challenges for the course. Our rationale was that, by understanding student perceptions of challenges, instructors can make instructional choices that aim to mitigate some of these concerns, thus helping to bolster sense of belonging and subsequent performance, disciplinary identity, and retention.

2 STUDY CONTEXT

Introduction to programming (INF100) teaches basic Python[1] programming. The subject is mandatory for all students at the Faculty of Mathematics and Natural Sciences, and the course enrolled 680 in the Fall 2022 semester. The course emphasizes groupwork sessions with programming exercises, and less focus on conventional lecturing. Each week is composed of a two-hour lecture and two group sessions where the students receive aid from group leaders[2] to complete the assignment of the week. To partake in the final exam (and finish the course) students must pass a number of weekly assignments throughout the whole semester. The survey we describe was conducted two days after the deadline of the first weekly assignment. At the time the policy was that students had to pass 7 out of 11 assignments to take the final exam, but this was reduced about a month into the semester. When reporting their challenges and issues for the course the students were informed of the 7 out of 11 rule.

Table 1. Answers to the prompt "How would you rate your programming ability in Python?" (n=436).

	%
Have not programmed before	50.69%
(1) Know a little	27.98%
(2)	12.16%
(3)	7.57%
(4)	1.61%
(5) Skilled	0.00%
Mean score	**1.65 / 5.0**

INF100 is for many students the first step into the world of computer science. The majority of students taking the course are starting their first semester in higher education, but one can find courses with programming in high school and lower. A survey issued in the first week of the course to map the prior programming knowledge of the students shows that 50.69% of students have never done any programming. The remaining 49.31% where asked to rate their proficiency in Python using a 5-point Likert scale (*Table 1*). Although nearly half of the students had coded before, the extent of their knowledge and experience was fairly limited, with a mean Likert score of 1.65 out of 5. Specifically knowledge of programming in Python was limited as only 36.47% students had experience with this language.

3 METHODOLOGY

The students were given a sheet of paper with the prompt *"Today, we'd like each of you to reflect on some of the concerns you may have about taking this course. What do you think will be difficult or challenging for you?"*. This prompt mirrors that used in [4] and [1], and was part of a larger study on student belonging in introductory-STEM courses. Students had 10 minutes to write before the sheets were collected. No phone or computer was allowed at the table during this time.

The responses from the students were transcribed and inductively coded [6] to group the concerns and challenges. A random sample of 30 responses was selected and categorized by two authors separately. When finished these where compared and a final set of categories were agreed upon, and then the remaining responses were assigned to these final categories. One response could be placed under several categories. All materials and responses have been translated from Norwegian.

4 RESULTS

The coded answers can be found in *Table 2*.

[1] https://www.python.org/

[2] A group leader is a student studying a bachelor or masters, who has a paid part time position in a course which they finished one or more years earlier.

Table 2. Coded answers from challenges prompt (n=176).

Challenges	**n**	**%**
Mandatory assignments	70	39.77%
Comprehension	60	34.09%
Programming language	49	27.84%
Little/no experience with programming	43	24.43%
Difficulty in self-study	38	21.59%
Deviation between theory and practice (lecture and assignments)	36	20.45%
Moving forward too quickly	32	18.18%
The curriculum is too hard	27	15.34%
Afraid of falling behind (the class)	24	13.64%
Steep learning curve	23	13.07%
The exam / failing	23	13.07%
Hard to find/use resources	20	11.36%
Advice/suggestions for teaching	17	9.66%
General concern for the subject	14	7.95%
The lecturers expectations	14	7.95%
Workload does not match the allotted time	13	7.39%
The math/logic part of programming	12	6.81%
Hard to get help	10	5.68%
Study technique	7	3.98%
No worries	6	3.41%
Issues with group sessions/leaders	6	3.41%

Of these challenges we focus our discussion on those that 10% or more of the students report, as these are the main concerns. The sum of students for each category is 544 which shows that many students expressed concerns that could be assigned to multiple categories.

The most common concern expressed by the participating students was *Mandatory assignments* (70 out of 176 student responses, or 39.77%). For example, two individuals wrote:

> *"Far too many difficult questions on the weekly assignments, which you cannot solve alone either."*

> *"Difficult to understand what the assignment is completely asking for, what is challenging is that there are submissions every week which makes it difficult to keep up."*

The first assignment[3] (which was due two days before these submissions) required the student to utilize the basics of the following programming concepts:

- Printing
- Reading input
- Conditionals
- Standard functions
- Custom functions

As there are no prerequisites for this course the students were expected to be able to solve these tasks after one week of study with no prior programming experience. This is considered a challenging task for new students. The course instructors plan was to start off with a heavy work load and slow down later in the semester, a plan that was not communicated to the students.

[3] The first INF100 assignment can be found here: https://inf100h22.stromme.me/lab/1/

Many of the other categories also relate to the difficulty of the course and the perceived performance of the students. Note that many of the comments below were assigned to multiple categories, but are shared here as exemplars for single categories.

Comprehension: 34.09%
"I am worried about looking too much at the solution and not understanding fundamental elements. I am worried about failing the course"

Programming language: 27.84%
"I think the content will be difficult because I have never programmed. Most of it seems Greek. In addition, it takes very little for a program to crash, and it is difficult to discover what is wrong."

Little/no experience in programming: 24.43%
"I have no previous experience with programming. Worried about not being able to find a solution on my own. Worried about dropping out from the start"

Difficulty of self-study: 21.59%
"I am most concerned about the subject's content because that I have no prior knowledge, and already notice that I understand very little. I also don't quite know how to work and do tasks on my own when I don't understand the tasks."

Deviation between theory and practice (lecture and assignments): 20.45%
"That the lectures do not deal with things in the submissions."

Moving forward too quickly: 18.18%
"The challenges are that we move forward very quickly. Difficult to understand without prior knowledge of the subject."

The curriculum is too hard: 15.34%
"My worries: that I'm not smart enough, the material is a lot and we rush through it."

Afraid of falling behind (the class): 13.64%
"Worried about coding badly and not keeping up with the rest of the class."

Steep learning curve: 13.07%
"The amount of material one must go through in a short time. The learning curve is so steep for the time you have at your disposal. Low learning outcomes from the lectures."

The exam / failing: 13.07%
"My worries are that I won't be able to code well enough for the exam. I'm worried that the material will be too difficult and that I won't learn anything. The learning curve has been quite steep so far and I'm worried that it will get even steeper."

Hard to find/use resources: 11.36%
"I think it can be difficult to know where I can find help in the resources we have been given, that I don't know where to look. It is also a little difficult to get to grips with python as I have not used it before."

5 DISCUSSION & CONCLUSION

Many of the reported challenges among the students pertain to the difficulty of the material, stating that the course is too hard. This might instill a feeling of inadequacy, a supposition supported by comments about personal shortcomings (lack of preparation, not being smart enough, not being able to keep up with the rest of the class). We realize that some of these student concerns might have been exacerbated by the timing of the survey (immediately after the first difficult assignment was due), however these

themes are consistent with student concerns expressed in other studies and we suspect future work will show similar responses, regardless of timing.

"My worries: that I'm not smart enough, there is a lot of material and we rush through it."

Fortunately, evidence-based instructional choices can mitigate some of these concerns. Prior work in the United States ([4, 1]) has demonstrated that brief, early-term interventions can have tractable benefits for students. For example, both [4] and [1] document significant benefits from a short exercise in which students discuss their concerns about the upcoming course, drawing from sample (fabricated) statements from prior students in the course. The aim of this ecological belonging intervention is for students to internalize that course challenges are temporary, normal, and surmountable, providing students with the mental tools to handle challenges proactively. Future work will aim to contextualize this intervention beyond the United States.

5.1 Future work

We aim to repeat the study in another iteration of the course, but this time we intend to collect personal information about the respondents to link their challenges with performance, gender and background. In addition, we would like to track these worries throughout the semester, surveying the students multiple times to differentiate between common start-of-semester challenges and those that persist. Finally, we plan to replicate the intervention documented in [4], to see if similar benefits are experienced in a Scandinavian, computer-science setting.

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