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Increasing student agency within courses via assignment tracks

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Abstract

Computing courses are taken by students with a diverse set of backgrounds, interests, technical abilities, degree programs, and future roles. Instructors face challenges in onboarding students, developing student interest, balancing different skillsets, reaching differently prepared students, and designing assignments that are fair and challenging to all students. This work presents an approach to designing assignments with an intentional emphasis on student agency. In one course, three parallel tracks of laboratory assignments were developed to allow students to pursue topics that were perceived to be personally relevant, useful, and meaningful. Despite the increase in faculty workload to develop and maintain a larger set of laboratory assignments, the multiple track concept mitigated many of the challenges facing instructors and increased the diverse set of students' interest in the domain. The success of this approach is demonstrated through an analysis of student performance data, informal student feedback, and formal course evaluations.

Keywords: instructional design, student agency, learner-centered design, information visualization, laboratory assignments

Introduction

Courses in the field of computing often leverage software-based laboratory assignments that guide students in a series of tasks. This coursework serves multiple purposes, including introducing students to software tools, expanding students' skillsets, preparing students for their professional roles, reinforcing theoretical lecture topics with practical experiences, assessing student proficiency towards learning objectives, and informing program assessment with performance data. These lab experiences have a notable impact on student learning and are often commented on within course evaluations and post-graduation surveys. Instructors face challenges within core courses that are taken by multiple programs and diverse student populations.

There are differences in backgrounds, academic preparation, technical competencies, future roles, desired skillsets, etc. At one mid-sized public university, there are undergraduate courses that satisfy requirements across multiple computing degree programs (i.e., IS, IT, CS, and cybersecurity majors) as well as general education electives that are available to a non-major. At the graduate level, core courses are taken by diverse student populations from four programs (applied computer science, cybersecurity, data science and analytics, and health informatics and bioinformatics).

Given the students' diverse prior academic backgrounds and broad future goals, laboratory assignment design is vital to achieve the coursework's purposes while also maintaining fairness and engaging all students. Developing coursework in light of learner-centered design (Soloway, Guzdial, & Hey, 1994) and similar educational theories is essential to meet the educational needs of diverse student populations.

Prior work has demonstrated the positive effects of student agency in making educational decisions (e.g., in selecting and persisting in a degree program, track and concentration, and elective) (Gale et al., 2022). Within a course, similar support for student agency builds motivation to attend class, engage with material, complete coursework, and build life-long interest in a topic. Developing student interest in a course topic is supported by principles from interest development theory (Michaelis & Weintrop, 2022). Successfully building interest requires students to find value, increase their knowledge, and gain a sense of belonging in regards to a topic. Laboratory exercises and other computing assignments need to be challenging, relevant, authentic, useful, meaningful, and expose students to the nature of computing-based problem solving. Linking assignments to a student's background and future goals is foundational in building interest (Pressick-Kilborn, 2015).

Providing students with the ability to tailor their assignments and experiences leads to association of the coursework with their own interests, identity, and existing competencies (Azevedo, 2015). Traditionally, computing labs aim to provide instruction on specific software, tools, and programming languages using methods that may be boring and unrelatable to students (Margolis et al., 2008). This prior body of work indicates that students benefit from coursework that allows for student agency in lab assignments.

Computing-based laboratory assignments taken by a diverse body of students may benefit from allowing students to tailor the experience based on their technical background, interests, and abilities. One School of Computing at a regional Master's University (Carnegie Classification) offers courses that combine students from multiple programs into integrated course sections. Two computing courses offered at the undergraduate and graduate levels (information visualization) were modified to allow students to tailor their semester-long set of laboratory assignments from a pre-defined set of computing platforms, visualizations software, and applied domains. These two undergraduate and graduate courses provide the context for this study.

The contributions of this paper 1) describe an approach to student agency centered course design in information visualization courses and 2) analyze the results of this approach in light of student performance, interest, and reflection.

Methodology

After experiences in teaching human-computer interaction and information visualization courses over the last ten years, instructors modified traditional laboratory assignments to increase student agency. Students at the graduate and undergraduate levels already had the option of pursuing semester-long projects on topics and techniques tailored to their individual interests (in addition to a baseline project suggested by the instructor).

This paper concentrates on modifying assignments within graduate sections of information visualization courses. Positive outcomes from these efforts to increase student agency at the graduate level was expected to justify expanding the approach to the undergraduate level and other courses in future semesters. In addition, positive informal outcomes of this approach may justify future controlled studies.

The key learning outcome for laboratory assignments was to guide students in designing visualizations that fulfill the information needs of specific intended audiences. Visualization courses often cover task-oriented and user-centered design processes that require students to model the tasks, insights, KPIs, and decisions for a set of users. Implementing interactive visualization designs requires a technical skillset to use existing tools (e.g., Tableau or Power BI) or develop new software for students with a programming background (e.g., JavaScript-based interfaces).

A wide range of software tools and programming libraries are available for this purpose. Software-based laboratory exercises enable students to gain competencies in implementing visualization designs and encourage students to explore their interests in learning more about particular approaches. Three laboratory tracks were designed to give students with varied backgrounds the ability to complete assignments with no-code, low-code, and coding intensive entry points. The definition and utility of supportive, reflective, and intrinsic scaffolding have been previously defined (Jackson, Krajcik, & Soloway, 1998). These series of labs support assignment *scaffolding*, an approach wherein learners engage in tasks that would otherwise be beyond the ability.

As the labs progress over the semester, the learner's knowledge, understanding, and abilities improve to the point where the scaffolding support can *fade* away. The different types of scaffolding support are described as follows:

> *Supportive scaffolding* in the laboratory assignments is provided through step-by-step tutorials with subtasks that cover the basics of using visualization tools and programming libraries.
>
> *Reflective scaffolding* in the laboratory assignments is provided by asking student to reflect on approaches that were encountered during and at the end of each laboratory.
>
> *Intrinsic scaffolding* in the laboratory assignments is provided by reducing the programming complexity and technical background required at the beginning of each track of laboratory assignments.

Over the course of five assignments, students encounter progressively fewer hints, more autonomy, and more open-ended subtasks. Three initial tracks were selected to provide a broad range of software options and multiple entry points for students to get started based on their own background. The first lab track covered a variety of different visualization software that students could execute on university servers or personal devices (with free student licenses).

The five labs included programming assignments as well as GUI-based software assignments. The second lab track covered interactive visualizations using Tableau with little to no programming required using cloud, university servers, or personal devices. A third lab track utilized the Google Cloud Platform (GCP) using free credits from the instructor with tutorials on building pipelines with visualization components. An extended set of future lab tracks were conceptually designed but not implemented in the initial offering.

Figure 1 overviews the initial set of software laboratory tracks as well as the potential expansion of tracks into new software areas. Instructors face a significant time commitment in implementing, writing, and testing new lab assignments. Instead of crafting five lab assignments, instructors had to craft three times as many individual labs to implement the three-track system.

Receiving overwhelmingly positive student feedback would be crucial for instructors to commit to continue allocating large investments of time to maintain, refine, and expand this set of labs in future semesters. After adopting this track-based approach to improving student agency, instructors evaluated student perception and performance via informal feedback questionnaires, formal student evaluations, and performance data.

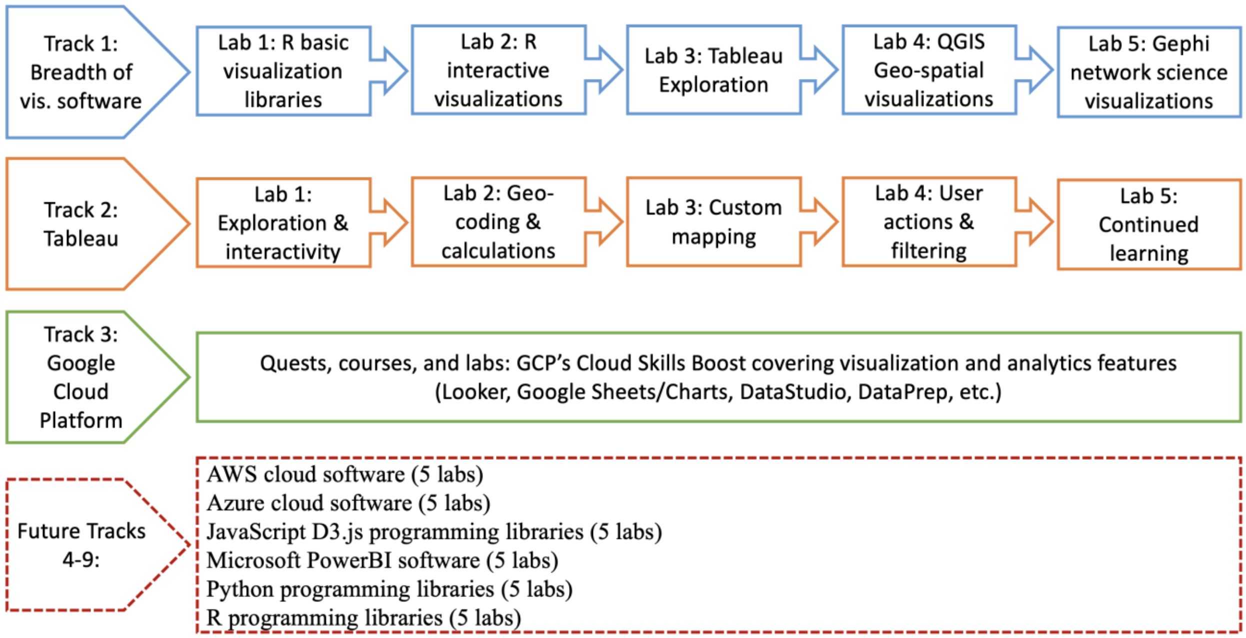

Figure 1: Existing set of three laboratory tracks and six envisioned future tracks.

Informal questionnaires and in-class discussions were utilized to gather initial feedback from three sections of 87 graduate students. Before and after completing the lab tracks, students were asked questions regarding:

- Do they understand and value student agency?
- Do they have concerns regarding fairness and grading if peers complete different assignments?
- Does agency boost their reported interest in a topic?
- Do students view modular labs and semester-long projects differently?
- What software do student perceive to be relevant and useful?
- Do students have preferences in how assignments are executed (e.g., utilizing personal, university or cloud resources)?
- Do online and in-person sections have similar perceptions?
- Do potential increases in student performance, motivation, and interest appear to justify faculty efforts required to create and maintain larger sets of labs? Faculty note the time required to acquire software licenses and resource credit allocations, update labs with new data and tasks, test and update labs with new software versions, and mitigate the potential for solution sharing by future students (i.e., cheating and collusion).
- Is there a difference in student performance in comparison to the prior 10 years of data for the instructor's information visualization courses?

Results

Student software preferences

Due to the time-intensive nature of developing and maintaining laboratory materials, the instructor was interested in informally tracking the actual interest, engagement, and completion rates of each lab track. Table 1 presents the breakdown of lab tracks selected by students. Student comments in class and on surveys reflected their appreciation for the initial set of tracks. Nearly all students highly recommended the track they completed for future students and recommended the instructor continue maintaining that track. Further data is needed to assess student preferences for tracks across different academic backgrounds and course modalities (online and in-person). The solutions that were turned-in were all fully completed by students and did not provide useful insights on completion rates and engagement. Several students who procrastinated and begin the tracks close to the due date were observed to get stuck on steps in the Tableau track and switched to the GCP track to mitigate their issues and complete their work on time. Student preferences were equally distributed across the tracks and reinforced the need to maintain all three options.

Table 1: The number of students in each section that selected and completed each track.

	Section 1	Section 2	Section 3	Total Students
Track 1: Breadth of Software	11	18	3	32 (37%)
Track 2: Tableau	11	5	10	26 (30%)
Track 3: GCP	9	10	10	29 (33%)
	31 students	**33 students**	**23 students**	

Academic performance

Student performance on the labs was reviewed. The instructor planned to estimate student engagement by tracking the time and completion rates of each track. The time spent and completion rates were consistent across tracks. However, in informal survey feedback, students that took the GCP track recommended the instructor require additional quests, courses, and labs in GCP as the platform tended to overestimate the time actually required to complete each lab. To estimate fairness between tracks, the grade distributions per track were compared and found to be equivalent. In the first track, students largely lost points from insufficient reflections. In the second track, points were largely lost due to minor details in encoding, formatting, and labeling final visualizations. In the third track, students had to fully complete all subtasks to receive their automatically generated cloud-based completion badge which forced students to receive full credit for GCP labs. The reflections in track three were completed sufficiently in contrast to some of the track 1 reflections. The grading analysis did not suggest that any significant changes were needed to ensure fairness between tracks.

Informal student feedback

Students provided their informal initial thoughts on coursework via two anonymous surveys before and after completing the tracks. Throughout the semester, students were routinely prompted to reflect on the assignments as the semester progressed. Students reflected on semester-long visualization projects, two-week labs, interest in specific visualization software, team-based and individual assignments, step-by-step tutorials versus open-ended assignments, time limitations, software expertise, programming backgrounds, envisioned future visualization and analysis software use, preferred environments (cloud, university servers, or personal devices), value of academic freedom and license, and consistency in assignment requirements.

The informal feedback on the lab tracks was consistent between student backgrounds and track selection. 51 students turned in informal feedback (which was highly positive) on the lab tracks after completing the course. They rated both an open-ended semester-long project and the lab track concept as "contributing to their understanding and practice of information visualization" with 9.5/10 ratings (a 0-10 scale). They rated themselves 9.6/10 in their "motivation in further learning about and using visualization software." This motivation increased (after completing the lab track) between the pre- and post-survey responses for 50 out of the 51 students. Students were evenly split between wanting to either concentrate on one software tool in depth or else learn about a broad range of other software options. Students rated themselves 9.7 out of 10 in terms of "how highly they value allowing for student choice and preferences in terms of elective course options as well as course projects and assignments." The informal comments closely aligned with educational theory on student agency. Commonly articulated informal sentiments included:

- It was 'nice' to be able to pick topics that aligned with their academic or professional interests. They recognized and appreciated the likely difference in student interests given the different backgrounds amongst peers.
- They were more engaged and enthusiastic when assignments were aligned with something they were really passionate about.
- They valued having the freedom to choose their own assignments and projects. The appreciated being able to work on something that interested them and was in line with their current skill levels.

In follow-up questions on student agency and freedom in lab tracks, 50/51 students highly valued student agency and acknowledged that students come from different backgrounds and have different preferences. Some students directly expressed their appreciation at being given the choice of multiple tracks. Only one student disagreed and thought that a single set of lab assignments would bring justice and transparency to evaluation. As this was the initial offering of tracks, this student (and the instructor) was not aware that assignment grades would naturally end up with identical distributions for all three tracks.

Tableau and Power BI were the two software packages that students expected to use in the future careers with 45 out of 51 students (88%) expecting to use one or both tools. 33% of students expected to also use Python or R. Singular students expected to exclusively use either cloud software, MicroStrategy, JavaScript, or Matlab. Consistent with the scaffolding concept, all students preferred to have step-by-step instructions (and not open-ended assignments) for software-based assignments, especially as beginners that were unfamiliar with new software. Students were evenly split between preferring to execute their coursework on cloud resources, university servers, or personal computers.

All 51 out of 51 students recommended that instructors continue using the lab track concept. Half responded that no new tracks should be added to the initial three tracks, while the other half recommended adding either Power BI, Python, JavaScript, SAS, or Apache Spark. Students did not have any significant suggestions for improving the lab tracks other than logistical recommendations on starting the labs earlier and modifying the deadlines for each lab.

The instructor designed all the individual labs for track 1 and 2 and partially utilized Google's cloud skills boost for track 3. Students in track 3 reflected on additional prompts to ensure the quality and utility of these public step-by-step tutorials. Students in prior semesters provided feedback that cloud-based timers for GCP labs added to the stress and increased anxiety-levels for the assignments as cloud resources generally shut down every 30-45 minutes. The instructor partially mitigated those concerns with forewarning, additional reassurance, and an unlimited bag of credits they were encouraged to fully use. 25 students in the GCP track provided informal reflections on student perceptions of the suitability of utilizing cloud software in visualization courses.

All students found the quests to be directly relevant to their anticipated careers and half thought the time requirements to complete the quests were overestimated by the cloud provider. All students found the quests to be intellectually stimulating and challenging at the graduate level. Some students in the GCP track expressed concerns that the current requirements were not quite sufficient to build their full confidence in the tools. 1/6 of students in the GCP track recommend that amount of work be doubled to improve student confidence in their abilities, knowledge, and familiarity with the platform. All students thought the set of pre-approved GCP visualization quests were easy to follow and should be continued to be offered in the future.

In summary, the informal feedback reinforced the instructor's understanding of student agency, student preferences, and justified continuing to offer the existing tracks and expanding the tracks in future semesters.

Formal student feedback

The university's anonymized official channel for student course evaluations provided another source of insights regarding the course modification. In all three graduate sections, the formal feedback directly aligned with the informal feedback already presented. The summative and formative course feedback was similar to the prior 10 years of course evaluations (taught by same faculty member). In questions regarding the intellectual stimulation of the course, a significant number of respondents positively commented on the interest and motivation being positively impacted by the lab tracks and the ability to focus their lab time on particular skills they expect to use in their careers.

Several students directly commented on enjoying the coursework and its direct translation towards their future roles. The labs tracks were the aspect of the course that contributed the most to their learning. The main suggestions for improving the course were to require more labs within each lab track and also expand the set of available lab tracks. In comparison to prior semesters, students increasingly commented on their perceived necessity to become proficient in the visualization software that is most in demand by their future employers. This feedback indicated that students appreciated and benefited from the increased emphasis on student agency within courses.

Discussion

The lessons learned in this work suggest that other courses that offer laboratory assignments may benefit from increasing the support for student agency within course assignments. This is especially relevant in courses wherein theoretical concepts could be potentially reinforced via multiple sets of parallel tasks and platforms (e.g., Android and iOS mobile app development, multiple machine learning frameworks, and NoSQL database systems). In these types of courses, faculty are able to develop parallel tracks of laboratory assignments that are independently sufficient for fulfilling the assignments' purposes. The performance on assignments and student feedback show that it is possible to provision a diverse set of assignments with fairness.

As expected, based interest development theory, students highly valued agency in the selection of assignments that aligned with their future roles and personal interests. Students highly valued developing their practical skillset related to implementing visualization designs. The increased emphasis on student agency may have been partially responsible for the increased perceived relevancy of the course assignments. After positive experiences in completing their lab track, more students than typical in prior semesters requested access to complete all the remaining lab tracks after the end of the semester (e.g., continued access to lab instructions, university servers, and cloud platform credits).

The positive perception of the lab tracks was rated as justifying the increased faculty effort needed to maintain large sets of labs. Students overwhelmingly appreciated step-by-step tutorials for tasks, software, and platforms that are new to them. A scaffolding progression of tasks within a series of labs was found to build confidence before students began exploring and developing proficiencies using on own. Focusing on student agency in assignments reinforced their interests by targeting their perceptions of relevancy, usefulness, and meaningfulness. All students reported their high valuation of agency with the majority of students reporting its success at increasing their interest to continue learning within the domain after the conclusion of the semester.

Given these results, the instructor plans to expand the set of available lab tracks based on the industry demands that align with stated student interest (e.g., Microsoft Power BI, Python, R, and cloud platforms). Another refinement will be to require the tracks to be completed by the midpoint of the semester to enable students to leverage their experiences towards a semester-long project.

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