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The Collaborative Disposition: What Students Say

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The Collaborative Disposition: What Students Say

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***Abstract*—This full research paper contributes to current work on fostering the collaborative disposition among computing and engineering students. Collaborative work is essential in computing and engineering, given the scope and complexity of the projects within these fields. However, little is known about how to cultivate this disposition in the undergraduate classroom. The motivation of this research is to identify the categories of behaviors that students associate with being collaborative. The research questions for this study are: 1) What do students describe as collaborative practices applied to their coursework? and 2) What do students report as factors that prevent them from being collaborative?**

In computing courses at three institutions, students were asked to complete programming assignments and complete a reflection prompt after each assignment that asked "*Describe an example of you being collaborative when completing this assignment. Otherwise, describe the circumstances that prevented you from being collaborative*". Responses were qualitatively/thematically analyzed resulting in the identification of ten categories of collaborative behaviors and nine categories of factors that impeded collaborative behavior.

The significance of the study is that it deepens understanding of the collaborative disposition and identifies conditions that promote or discourage it. The results of this work will help educators design classroom interventions that will facilitate the development of the collaborative disposition among computing and engineering students.

***Index Terms*—Undergraduate, multi-institution, professional dispositions, qualitative analysis**

I. Introduction

The *collaborative disposition* is one of eleven dispositions identified in the ACM/IEEE Computing Curricula (CC2020) report [1] as being critical to all students completing computing degrees. According to CC2020, one who embodies the collaborative disposition is viewed as "a team-player" and "willing to work with others". A *disposition* is a mindset or attitude that encourages and facilitates positive behavior(s), such as those that lead to successful collaboration. A disposition involves the ability to apply a behavior along with both a recognition of the opportunity to apply a behavior and the inclination or willingness to apply the behavior [2]. The collaborative disposition is not to be confused with *collaboration skills*, which are the specific, demonstrable behaviors or abilities needed for successful collaboration, such a teamwork, communication, and problem solving. Educators and employers agree that professional dispositions are important; what is not fully understood is how to teach or instill dispositions to/in students. The good news is that research has shown that dispositions are malleable [3], giving hope to educators and motivating this work. The ultimate goal of this research is to gain an understanding of how to foster dispositions among students.

In this study, we investigate how students view the collaborative disposition by identifying the behaviors students associate with being collaborative. An understanding of how students view being collaborative, and the awareness of factors that prevent students from being collaborative, will aid educators in crafting educational experiences and pedagogic materials that are useful in fostering/instilling dispositions in students. The research questions that guide this study are:

RQ1: What do students describe as collaborative practices applied to their coursework?

RQ2: What do students report as factors that prevent them from being collaborative?

II. Relevant Background

The concept of disposition first emerged in educational theory research. Dewey proposed the idea of "habits", as "an acquired predisposition to ways or modes of response" ([4, p.42], cited in [5]), which was similar to the more recent concept of disposition. Perkins et al. [2] proposed a definition of disposition with three components: inclination (a person's tendency towards a behavior), sensitivity (a person's alertness to occasions in which a behavior is needed), and ability (a person's ability to engage in the behavior). Freeman [6] describes a similar model of disposition, composed of values, intention to act, strategies of carrying out the action, and the context in which the action takes place. Our view of professional dispositions as values, beliefs, and attitudes that lead to desirable behaviors in the workplace is related to these earlier definitions. Similar definitions can be found in computing education literature [7]–[10]. Being collaborative is frequently mentioned as very important to employers and therefore is heavily studied in computing education research. For example, Babb et al. [11] conducted a literature search that found that the collaborative disposition was one of the two most studied dispositions.

Collaborativeness has been studied as both a skill and a disposition. The importance of collaboration as a skill is evidenced by several general-purpose assessment instruments (Program for International Assessment (PISA) [12], Assessment and Teaching of 21st Century Skills [13], and those by Educational Testing Service [14]). For example, in the PISA assessment, collaboration is seen as a collection of competencies: establishing and maintaining shared understanding, taking appropriate action, and establishing team organization [15]. In contrast, others focus on collaborativeness as a disposition. For example, a study based on a systematic literature review and feedback from industry professionals [7] identified collaboration, communication, and teamwork as interrelated professional dispositions. A similar study [8] identified collaborativeness as comprising three dispositions: being sociable, being a team player, and being able to navigate social dynamics. Fransen et al. [16] and Li [17] emphasize the concept of team orientation, defined as team members' attitudes towards teamwork. In this study we also focus on *collaborative* as a disposition.

In the education literature, collaboration has been studied in the context of collaborative and cooperative problem solving. Collaborative problem solving is defined as an activity involving two or more people who need to solve a problem or accomplish a goal which can not be achieved individually; it requires both social skills and cognitive skills [15], [18]. Cooperative problem solving is an activity that is handled through division of labor - participants may meet to coordinate but typically work in parallel [18], [19]. The terms collaborative and cooperative in the context of problem solving have often been used interchangeably. In this study of the collaborative disposition we are mindful of both collaborative and cooperative problem solving.

III. Methods

We conducted a thematic content analysis of student responses to an open-ended question about how students were collaborative (or not) while doing coursework. The analysis addresses the research questions posed in Section I. The participants in the study were students enrolled in three undergraduate computing courses at three institutions of higher education in the US. The institutional review boards of the participating institutions approved the research study (IRB-FY2022-53, IRB-FY2022-65, and IRB-627).

We conducted the study during four consecutive terms over two academic years, 2022–2023 and 2023–2024. A total of 174 students consented to participate in the study, of whom 160 responded. They were enrolled in two lower level courses (Computer Science I, and Data Structures Fundamentals) and one upper-level course (Database Management Systems). The profiles of the institutions varied: public versus private, residential versus commuting, and liberal arts versus professional versus comprehensive. By collecting data from multiple courses at different institutions over multiple terms we could capture the perceptions of being collaborative from a wide variety of students.

A. Data Collection

In each course, three to four assignments were enhanced with a *reflective exercise*, required of all students, including those who had consented to participate in the study. The reflective exercise presented students with a definition of *being collaborative*: "Collaborative means to work with other people as a group, exchange, share and discuss ideas, thoughts, feedback and solutions to a given problem or task." Following the definition, an open-ended *reflection prompt* asked students to either give an example of how they were collaborative while completing the assigned work, or to describe circumstances that prevented them from being collaborative. Over the four academic terms of the study, 160 participants, enrolled in 10 sections, provided 364 responses to the reflection prompt. Table I shows the distribution of course sections, participating students, and their responses across the three courses from which data were collected. Three of the six authors taught all of the sections except for one section, which was taught by an author's colleague. The participants included 96 male, 36 female, 27 Asian, 17 Black, 70 White, 14 Hispanic, 107 computing majors, and 25 non-computing majors.

TABLE I
COURSE SECTIONS, PARTICIPANTS, AND STUDENT RESPONSES IN THIS STUDY

Course	CS1	Data Structures	Database Management	Total
Sections	5	1	4	10
Participants	89	4	67	160
Responses	238	4	122	364

B. Data Analysis

Mayring's qualitative content analysis [20] was used to identify categories of collaborative behaviors (RQ1) and categories of factors that prevented students from being collaborative (RQ2). For analysis, each complete student response conveyed one meaning and was treated as one coding unit. A total of 364 coding units were analyzed (corresponding to the responses shown in Table I).

The authors of this paper comprised the study's research team. Three researchers independently analyzed the first 100 responses by starting with an initial set of seven deductive categories of collaborative behavior: general communication and exchange, problem-related communication, interactive problem solving during group collaboration, independent problem solving during group collaboration, asking for help, assisting others, and sharing resources. These categories were built prior to this study [21], [22], from analyzing student responses collected from reflective exercises over a short period of time of two academic terms. After the initial set of responses were analyzed independently, the researchers met multiple times, discussed their interpretation of student responses, raised questions about the categories' definitions, and determined that the initial set of deductive categories did not fit the responses.

Two of the three researchers continued the analysis independently by applying a deductive-inductive approach to the entire dataset. Then they worked together to systematically compare the data across emerging and refined categories. During an iterative process, they identified and analyzed new patterns, and repeatedly revised and narrowed down categories until they reached consensus [23]. Of the 364 responses, 72 described factors that prevented students from being collaborative. These responses were analyzed inductively by another team of two researchers, who followed the same process: coding independently first, and then continuously comparing, rewording, and reconstructing categories. In the end, the entire team met in multiple sessions to discuss and finalize the categories' names and definitions.

To ensure the trustworthiness of the analysis process and to build credibility [24], the researchers spent extensive time in their application of the constant comparative method [25]. Credibility was also promoted by two triangulation methods [26], [27]: 1) data triangulation of multiple sources from different courses at different institutions, over four consecutive academic terms; 2) investigator triangulation through the participation of six researchers from different institutions. The researchers maintained rigorous and meticulous documentation of the research steps and the rationale behind category development to ensure the transparency and dependability of the analysis process.

IV. Results

The coding unit for data analysis was a complete individual student response. Student responses, quoted verbatim in this section, are identified as R#, where R signifies a response and # represents the unique ID of the response. There were 160 participating students who contributed 364 responses to reflective exercises that accompanied 3 to 4 assignments during an academic term. Of those responses, 234 included descriptions of students' perceived collaborative behavior. These 234 responses were coded into ten behavioral categories, whose names and definitions are listed in Table II. The response frequency for each category is shown in parentheses by the category name. Of the remaining 130 responses, 72 indicated the student was not collaborative (see Section IV-B below and Table III). In the remaining 58 responses, we did not find sufficient information to determine collaborative behaviors or factors preventing collaboration and thus they were excluded from our analysis.

Some responses are descriptive of a primary behavioral category along with one or two secondary categories. For example, in this response "I do reach out to my tutor, and ask professor for clarification when working on the assignment. I do reach out to the course tutor for a help, and track discord discussion with classmates." (R204), the primary theme relates to help, specifically *asking for help*. A secondary category in support of reaching out for help is *using tools*, such as Discord, to monitor discussions that complement help from a tutor or course instructor. Other secondary categories, which were mainly associated with group collaboration primary categories, include *communication* and *problem solving*. The following response is an example of *interactive formal group collaboration* (primary category). It illustrates that students integrate the feedback received in their project, while emphasizing *communication* (secondary category) in support of their collaboration: "An example of myself being collaborative when completing this assignment can be seen in our communication discussing what we are doing for the assignment. Me and my group member communicate with each other to decide what we are doing in the project and discuss the feedback given from previous assignments" (R52).

A. RQ1: Behaviors for Being Collaborative

Table II lists ten categories of collaborative behavior students described in their responses. The first three categories characterize group collaboration behaviors. These categories showcase that students worked collectively as a formal group to co-create products (*interactive formal group collaboration*), worked with others outside of a formal group (*informal group interaction*), and worked with a formal group but split the workload into individual contributions (*independent formal group collaboration*). The following four categories, *asking for help*, *assisting others*, *unsolicited help*, and *helping each other*, share help-related behaviors. The last three categories represent collaborative behaviors that are neither indicative of the explicit involvement of a particular group, nor focused on help-related behaviors. These categories were identified as primary themes in responses by which students paid exclusive attention to *communication*, *problem solving*, and *using tools* as collaborative behaviors.

1) Interactive formal group collaboration: In this category, students work together in a formal group as a team or partners to complete a variety of tasks spanning all parts of a typical project: "An example of me being collaborative during this assignment would be me coming together with my partner and brainstorming our ideas. At time [*sic*] there may have been a difference in ideas, but we came together to form one product. We both used our knowledge to the best of our abilities to aid in the completion of our project" (R162). Common types of student interactions included brainstorming or exchanging ideas, providing and discussing feedback, jointly making decisions, and working together synchronously on a design or implementation task.

The exchange of ideas and feedback often happened at the same time through a process of "bouncing ideas off one another" throughout the work: "me and my partner went through many revisions and back-and-forth exchange during the creation and alteration of the many tables and the table-population in order to get it to a level we were both satisfied with" (R450). At times, teammates also discussed external feedback, such as from the instructor: "My partner and I

TABLE II
BEHAVIORAL CATEGORIES FOR BEING COLLABORATIVE

Name	Definition
	Group collaboration categories
Interactive formal group collaboration (60)	Formal group of a team or partners working together and co-creating work products
Informal group interaction (46)	Working interactively with others without a formal group
Independent formal group collaboration (36)	Formal group working independently and building work products by merging individual contributions
	Help-related categories
Asking for help (35)	Reaching out to other individuals for guidance on problems/issues encountered with the assignment.
Assisting others (10)	Giving input and sharing insights with classmate(s) regarding coding errors, project solution, or concept understanding
Unsolicited help (7)	Having partner or classmate help without being asked
Helping each other (6)	Offering and getting help in a reciprocal manner
	Supportive categories
Communication (19)	Talking, sharing ideas, and keeping contact with peers, group members, friends, or others
Problem solving (11)	Identifying, discussing, and resolving problems or issues
Using tools (4)	Supporting collaboration through the use of resources, such as Discord or Google Docs

viewed each others assignment and chose one of the 2 to improve based on the feedback we received. From there we worked on every feedback the teacher provided and came to an agreement on the ER Model" (R21). Teams exchanged multiple rounds of feedback and used this feedback to iterate on their work: "For our table schema we did it on a google docs [*sic*] and as we went along we commented on each's contribution making corrections and suggestions" (R45). While many joint decisions made by the team were technical and related to the design or implementation of the final product (R21), some decisions concerned the team's approach to the project or code: "My team was constantly bouncing ideas off of each other in relation to how we should format our code, and what approach we should take when it comes to completing a project / phase" (R247).

Synchronous collaboration took many forms, involving a range of tools and tasks. Sometimes this collaboration was in person and in a formal class setting: "Working with partners in lab, using communication with them to achieve goals" (R335). In other instances, students communicated through text (both SMS and messaging apps), calls (phone and video), and collaboration tools (most commonly Google Docs). This sometimes involved pair/group programming: "Being the main screen in which I typed out code while leading a discussion on how to write the code for problem 1 with my group members" (R187). Sometimes, collaboration would help to find or prevent bugs in students' code: "Small syntactical errors would affect our database's ability to run as intended, so it was important to have an extra set of eyes" (R458). And this collaboration was sometimes deliberate, organized in advance and with a specific purpose such as verifying the final product: "My partner and I set up meeting times for us to work on the project together. When we translated the ER model into tables, we went through each of the entities together, making sure weren't missing any information" (R152).

2) Informal group interaction: Informal group interaction refers to the situation in which collaboration does not occur as part of a formal group (e.g., project team or pair programming group) and is not specifically and solely about asking for or obtaining help. It can occur in many contexts: in the classroom or lab, outside of the classroom, over time in various circumstances, working together to solve a problem, sharing ideas, or while studying. It often occurs in person, but also occurs in online forums such as Slack or Discord, as well as by phone calls or text messaging. Many responses described working together synchronously to complete an assignment. An example is this response "[student name] and I completed the assignment in one sitting. We communicated over the phone with [student name] using the word processor to document our answers" (R40). Another group of responses described sharing ideas, for example "There was a classmate next to me that was working on passwords 4words at the same time that I was and we had shared ideas on how to complete this section of the project" (R219). Other responses included instances of students learning from others and interacting in study groups.

3) Independent formal group collaboration: While the background literature [15], [19] distinguishes between collaboration and cooperation and this category is clearly cooperation, we are including it as a category under collaboration because we are interested in how students view collaboration and it appears they view cooperation as a form of collaboration. In this category, students make sure that they are on the same page with respect to task allocation and the final product. As summed up by one response: "We talked about what had to be done, separated the work then checked each other to make sure we agreed on everything" (R54). In allocating tasks, dividing the work evenly was repeatedly mentioned: "we split the number of tables that we had to create so i *(sic)* did one and he did one" (R62). The tasks allocated were not necessarily the same: "... He completed the tables, while I created the SQL database" (R454). Individual tasks were also not necessarily done in parallel: "My partner and I take turns in doing the assignment" (R293).

In some cases, teammates would share information or exchange ideas during their individual tasks: "We were collaborative by keeping each other updated on our progress during the project and made sure that we both had up to date tables and information" (R92). In addition to task management, this was also useful for coordinating dependent tasks: "As soon as my partner finished his part he updated me immediately so I can begin working on mine" (R149).

Periods of individual work were followed by a "merge" step to join the work into an intermediate or final product. This included ideas and prototypes: "... We worked independently and brought our ideas together in brain-storming sessions which helped us merge ideas and concepts" (R88), or "…We looked at each other's and discussed what we liked and didn't like about each other's models and we worked on what we should create next" (R178). At the conclusion of a project, this merge step involved checking that the final product worked as intended: "…Upon completion, we did a final check if the database and queries run correctly" (R85).

4) Asking for help: There are four forms of collaborative behavior involving help: *asking for help*, *assisting others*, *unsolicited help* without explicitly asking for it, and *helping each other* (see Table II). In all the help-related categories, students interacted with one or more classmates, peers, friends, partners, Discord participants, or relatives. Only responses in the *asking for help* category named tutors and teachers as individuals to whom students directed their call for help. Programming issues were prevalent among student responses across all four forms of help. Response R185 exemplifies *asking for help* with a programming task: "During problem 3 of the recent project, I reached out to a fellow classmate on how to incorporate a new function into the code."

The majority of the help-related responses are in the *asking for help* category (35 out of 53). This category has the widest range of motivations for engaging in collaborative behavior, such as being stuck or unfamiliar, finding the right approach or different ways to understand or apply knowledge, thinking of new ideas when solving a problem, or studying for a test. For example, a student said: "I ask other people how they solved the same problem as me to find different ways that I hadn't thought of before" (R418).

5) Assisting others: Giving input, exchanging knowledge, or understanding concepts were among the motivations of the students who assisted others: "I have been collaborative with my classmates before and after class by talking to them and helping exchange knowledge on how to perform certain aspects of coding" (R304). Here is an example that describes an instance of *assisting others* with coding: "I answered [student name]'s question about the count() method in discord and helped clarify his confusion" (R107).

6) Unsolicited help: In some cases, students received help with reviewing or explaining code, or learned from partners without explicitly asking for help: "There were areas of knowledge that I was shaky on that my partners knew well, I learned from them during those " (R414).

7) Helping each other: Other instances describe reciprocal help: "Before exams, we help each other to understand to understand the material better" (R436).

8) Communication: Responses in this category describe collaborative behaviors centered on communication, such as checking up on status, keeping in touch, comparing or bouncing ideas, or giving feedback: "I often try to converse with friends about an assignment a little bit if I get stuck to see if any conversation on the topic helps clear same stuff up" (R384). All the responses in this category focus specifically on communication, rather than elaborating on group interaction (tasks and work products) or help activities, or detailing on problem solving steps or tasks. Students reported communication with group members, peers in the lab, partners, classmates, friends, or other people. Most responses identified project partners or group members, which might suggest that the communication facilitated a group interaction. However, besides the attention given to communication as a form of collaboration, the responses had no information about collaborative group activities, and thus the *communication* category was applied. Meeting out of class time, talking over the phone, texting, and sharing files or a working environment were among the modalities that facilitated student communication.

9) Problem solving: Responses in this category focus on solving problems or resolving issues that students identified in their assignment work: "For the homework problem #1, [student name] and I had to collaborate to figure out to do one of the sections and get it the right way" (R188). With a peer or within a group, problem-solving activities involved figuring out a solution and pulling in their collective knowledge. Similar to *communication* and *using tools* categories, the *problem-solving* category is also a frequent secondary theme in group collaboration categories.

10) Using tools: Being collaborative was supported through the use of tools. Four responses focused exclusively on this aspect of collaboration. Students mentioned Google Docs and Discord chat service, for example: "I read through the discussions that occurred on discord […] I still learned and interacted with my classmates" (R99). This category was also identified as a secondary theme in many of the other categories, in particular group collaboration categories.

B. RQ2: Factors for Not Being Collaborative

Of the 364 total responses, 72 responses were classified as *the student did not apply the collaboration disposition*. These responses were categorized into emergent themes, as shown in Table III. Each theme is described below.

1) Assignment structure: The most prevalent category for not being collaborative was that the assignment and/or course structure did not permit collaboration, did not encourage collaboration, or did not require collaboration. In some cases, students clarified the assignment was assigned as individual work: "I wasn't collaborative on this assignment because I had no need to be. This assignment was assigned individually and I did it at home away from anyone who I may have collaborated with usually had I gotten stuck" (R205). Others referenced the lack of group work in the course culture, such as "There has been no group work so no collaboration" (R327). This response explains that while laboratory exercises were completed in formal groups, it was not clear that the out-of-class course assignments were intended to be collaborative: "As this was a homework assignment and not a lab, I was not aware that collaboration was an aspect of this assignment. Because of this, I completed this assignment on my own, though I did ask a clarification question over discord" (R211).

2) Situational barriers: Some students described situations that prevented them from being collaborative. One student indicated an unresponsive partner: "This portion of the project

TABLE III
FACTORS PREVENTING STUDENTS FROM BEING COLLABORATIVE

Name	Definition
Assignment or course structure (33)	To the student, the structure of the assignment and/or course does not need the collaboration disposition to be applied or the assigned work is individual
Situational barriers (9)	Circumstances such as illness created a barrier to being collaborative
Self-sufficiency (9)	Given their own skills, student believes that they do not need to apply the collaboration disposition
Referred to reflection vs assignment (7)	Answered question about being collaborative when completing the reflection prompt vs the course assignment
Identity misalignment (5)	A component of the student's self-described identity is misaligned with applying collaboration disposition
No particular reason (4)	Simply stated they worked on the assignment alone
Competing commitments (3)	Other commitments (work, personal) prevent them from applying collaboration disposition
Insufficient motivation (1)	The student is not motivated to apply the collaboration disposition or to participate in the course.
Unsuccessful effort (1)	The student tried, but could not successfully apply collaboration disposition (e.g., due to lack of understanding or getting stuck on a problem)

proved to be difficult to find an example of collaboration for. This was due to my partner, for unknown reasons, not responding to my requests to work on the project. However, this provided me with a fantastic opportunity to better learn and understand the material" (R160). Another response showed a student had no one with whom to work. One response stated the student worked at home instead of on campus. A few responses mentioned they did not have time to start on the assignment in class when collaboration typically occurred or that they missed the class session when the collaboration happened. For example, one response states: "I was ill and felt like I did not have the capacity to effectively communicate or reach out to other classmates" (R259).

3) Self-sufficiency: If the response indicated that the student could complete the assignment without help and did not need to collaborate, the response was coded as indicating "self-sufficiency". This response exemplifies this situation: "I didn't collaborated with anyone on this homework, because the topic was very familiar to me and we had done a few of this type of work before" (R136). Another response mentioned that the student ran into issues, but figured them out on their own: "I didn't think to ask for help in discord when running into an issue, i *(sic)* brute forced my way into an answer by looking up the different methods and built in function in python to see what tools i *(sic)* had to complete the assignment" (R200).

4) Referred to reflection vs. assignment: As the authors coded the responses, it was clear that some students answered the reflection prompt about being collaborative with respect to completing the reflective exercise instead of completing the course assignment. Students referred to the reflective exercise as a survey. Here is an exemplar for this category: "I can not be collaborative on this assignment due to it being a one person survey" (R325).

5) Identity misalignment: Responses in this category show that students had work-style preferences for working alone versus working with others. Here is an example: "I have social anxiety so collaborating is difficult" (R323). Other responses indicated a preference for working alone: "I usually work on my homework by myself and prefer to work alone therefore my own preferences would be the circumstance preventing me from being collaborative" (R406).

6) No particular reason: Responses in this category simply stated they were not collaborative because they worked alone on the assignment. They did not include a reason why they chose to work alone. For example, one response stated: "I was not collaborative because I worked alone" (R404).

7) Competing commitments: Three responses mentioned other tasks that prevented them from being collaborative. Two mentioned workload for other classes. One mentioned the need to spend time on homework on the weekdays and with family on the weekends. This category is similar to *situational barriers*, but specifically included workload reasons and not other types of situational barriers. One response states "I was running late for my project due to heavy workload during the weekdays and my family was here so I had to spend sometime on the weekends with the family. Due to this I was not able to collaborate with anyone for this project" (R118). Another states "I needed to get this homework assignment done quickly so I could move on to other work. While it posed some interesting challenges that I would have liked to have seen some different perspectives on, I wasn't willing to wait around for Discord responses" (R142). The final response in this category states "I was not able to collaborate with anyone for this assignment because of work from other class and exams from other classes" (R144).

8) Insufficient motivation: Just one response was coded into this category: "I was not collaborative because I have lost all motivation for this course and did not do the homework problems" (R140).

9) Unsuccessful effort: This response showed the student tried, but could not figure out how to complete the assignment: "I was not collaborative because I couldnt *(sic)* figure out how to complete the assignment" (R147).

V. DISCUSSION

While the primary aim of our study is to understand student perceptions of the collaborative disposition (namely, behaviors and barriers), our long-term aim is to help educators better foster the collaborative disposition in their teaching. With this in mind, we discuss guiding principles for educators, based on several key themes we observed across our results from Section IV. The next three subsections roughly align with the constructs of sensitivity, inclination, and ability described in the dispositions model of Perkins et al. [2].

A. Create and Highlight Collaboration Opportunities

As described in Section IV-B, one of the most common barriers to collaboration was a student's perception that a task or assignment was not meant to be done collaboratively. While students were at times asked to complete assignments individually, in some cases, students were not aware that collaboration was allowed, and indicated that they would collaborate if given the opportunity: "...If the assignment called for collaboration I would be all for it" (R255). In some cases, the type of assignment (e.g., lab or homework) led students to perceive that collaboration was not allowed Some students also perceived some types of collaboration (e.g., asking peers for clarification) as acceptable even if they did not perceive the assignment as allowing collaboration.

Fostering collaboration, then, requires not only creating assignments that allow or require collaboration, but also drawing attention to these aspects of the assignment, and being clear about what kinds of collaboration are allowed or prohibited. This may include clarifications on when collaboration is allowed (e.g., what kinds of assignments), what behaviors are permitted (e.g., providing problem-solving approaches versus sharing code), or who is allowed to collaborate (e.g., teammates versus other classmates).

Even outside of these more formal opportunities to collaborate, the responses we analyzed also demonstrate that students find, and make use of, a wide range of opportunities to informally collaborate. Informal collaborations can occur remotely using messaging apps or shared documents, and may also occur spontaneously in class as students share a working space and help one another understand concepts or solve problems. These opportunities may arise due to course structure (e.g., lab sessions where collaboration can occur in person), but may also be created by students themselves (e.g., study groups).

By creating spaces for these informal collaborations, whether in person or remote, in class or out of class, instructors can create and facilitate further opportunities for their students to collaborate. Even when these spaces are created by students, instructors can facilitate collaboration by highlighting these opportunities or providing students with the ability to do so (e.g., a classwide messaging server).

B. Emphasize the Value of Collaboration

Our results show that even if students recognize the opportunity to collaborate, they may not be motivated or incentivized to collaborate. In some cases, they may feel that they can easily complete the assignment on their own, or they may prefer working alone. In some cases, students do not view collaboration as worth the effort: "...I would enjoy working with a group but with all of the assignments mainly being for 1 person it is just easier to do it by yourself" (R229). In other cases, students may be discouraged from collaborating to avoid potential academic integrity violations. For topics, courses, or programs in which collaboration is highly valued, instructors can explicitly signal this value by creating learning objectives or assignment requirements centered on peer collaboration. Additionally, instructors could explicitly reward exemplary collaboration, such as for providing high-quality information or feedback on course messaging platforms (e.g., Canvas, Discord).

Where collaboration is an explicit learning objective, it is important to consider the overall context of the assignment within the course or the course within the overall program. Particularly in early courses, instructors may prefer that students work to build foundational technical skills as individuals, and emphasize this objective more strongly relative to collaboration. Dispositions are developed over time [5], and our results reflect this, with students not collaborating even in courses that attempt to foster this disposition (Sec. IV-B). Instructors should thus consider their own course and program contexts, and make intentional decisions about which dispositions to foster in their respective courses, and to what extent.

Even in the absence of learning objectives or formal collaboration requirements, however, our results demonstrate that students collaborate in a wide variety of ways to achieve a range of desired outcomes, including the generation of good ideas, help understanding concepts, refinement of designs through feedback, debugging, testing, and preparing for exams. Even for students who could solve problems on their own, collaboration highlighted alternative solutions, which can be valuable in deepening understanding. Instructors can help students more clearly see the value of collaboration by explicitly drawing attention to these benefits of collaboration, as well as through the design of learning activities that promote these insights, such as pair programming or peer feedback exercises.

C. Teach and Foster Collaboration Practices

Our results indicated that some types of collaboration were built explicitly into the course or assignment structure: "...we had to discuss the feedback given related to our ER models and use that feedback to create a finalized version" (R4). Instructors can teach specific techniques for these types of tasks, providing students with the opportunity to practice these techniques in class (potentially with some scaffolding). Even in the broad range of informal collaborative behaviors described above, instructors can highlight approaches or techniques for more effective collaboration. This may be particularly useful for activities such as reviewing design/code, pair programming, or debugging, where the individual and collaborative analogs of these activities differ significantly.

We see from our results that students primarily perceive collaboration as behaviors centered around communication with peers. Few reported collaborating by communicating with others, such as tutors, teaching assistants, or instructors, even though these could help accomplish the same tasks. Instructors may thus find it useful to have students explore, and thus more deeply understand, collaboration techniques, such as by contrasting their perceived collaborations with other types of communication, or by teaching techniques from existing literature, which puts greater emphasis on the confluence of cognitive and social skills for collaboratively solving problems [15], [18].

Finally, as we described in Section IV-B, a variety of factors can hinder students in being collaborative. In the case of formal teams, if a student fails to be collaborative, this also affects their teammates. Instructors may thus find it helpful to teach students techniques not only for collaboration, but also for navigating team conflicts that may arise.

VI. Limitations

The authors designed the study, methods, and data collection protocols to be generally applicable to several institutional contexts, a variety of courses, and several types of assignments and projects. However, interpreting responses without knowing specifics about how students were directed to work and the assignments themselves proved challenging for the research team. For example, the research team did not have access to the course assignment descriptions, if assignments had individual or group submissions, the duration of the assignment, and the general working mode in the course (individuals, pair programming, formal groups).

Another limitation of this study is the student population from which the data was collected. Even though data was collected from three institutions and three courses, most students were enrolled in lower-division courses. CS1 and Data Structures are more foundational courses in which collaboration may not be as heavily emphasized. The lower-division students in this study (93 of 160) may not have as much experience working in formal teams. The balance of the lower-division versus upper-division student populations impacts the types and frequencies of collaborative behaviors that were reported.

VII. Conclusion

This study analyzed 364 student reflections to more deeply understand student perceptions of their own practices associated with collaborativeness, and factors that prevent them from being collaborative. The study identified ten types of collaborative behaviors and nine factors that hinder students' collaborativeness. These findings provide insights into how students perceive their own collaborativeness. These results highlight a need to more thoroughly explore the extent to which students are not only aware of opportunities to be collaborative, but also motivated to be so. Employers highly value the collaborative disposition and associate it with the practice of teamwork. Instructors play a role in instilling the collaborative disposition by providing opportunities that enable students to develop the skills required to be effective and confident collaborators, making them more valuable in the workplace. These results can inform the design of courses and learning experiences that allow students to practice this critical disposition.

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