Do Affordances of Classroom Furniture Affect Learning in Undergraduate Active-Learning Courses?

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Abstract: Undergraduate education is moving from traditional, lecture-centric instruction toward approaches that reduce lectures and increase collaborative activities. Yet, many institutions do not have enough classrooms outfitted with furniture that provides ideal support for collaborative interactions over shared course materials. Consequently, many instructors teach in classrooms with furniture that may not afford effective collaboration. Does classroom furniture affect undergraduate students' learning from courses that utilize active-learning approaches? We explored this question in three undergraduate chemistry courses that placed a focus on collaboration with shared physical and virtual resources. 2,651 students in 136 sections were taught in classrooms with different furniture: traditional tables, traditional chairs, group chairs with or without wheels, and group tables with monitors. We found that low-performing students had significantly higher course grades if their classroom had group tables or flexible chairs. Further, a survey with teaching assistants revealed how teaching strategies may compensate for suboptimal classroom furniture.

Introduction

Many faculty who seek to encourage active learning and collaboration in their undergraduate courses are disappointed when they find out that their assigned classrooms do not easily afford collaborative interactions (e.g., Figures 1A and 1B). Can they still teach an effective collaborative course, even if the classroom furniture does not optimally accommodate the interactions they want students to engage in—or should they request a room change? At a theoretical level, this question relates to the extent to which affordances of classroom designs affect students' learning. This question is also of practical relevance because purchasing new furniture designed to support active learning (see Figure 1E) may lead some to question whether hundreds of thousands of dollars are worth the investment. Finally, this question is timely as undergraduate education moves away from traditional, lecture-centric instruction toward active-learning approaches that engage students in interactive and collaborative interactions (Chi, 2009; Rau et al., 2017), and many active-learning approaches replace in-class lectures with collaborative small-group activities (Bradley, Ulrich, Jones Jr., & Jones, 2002; Rau et al., 2017). These activities typically incorporate technology-based as well as paper-based materials, as shown in Figure 1E. These materials require considerable space, especially when students share materials to co-construct knowledge.

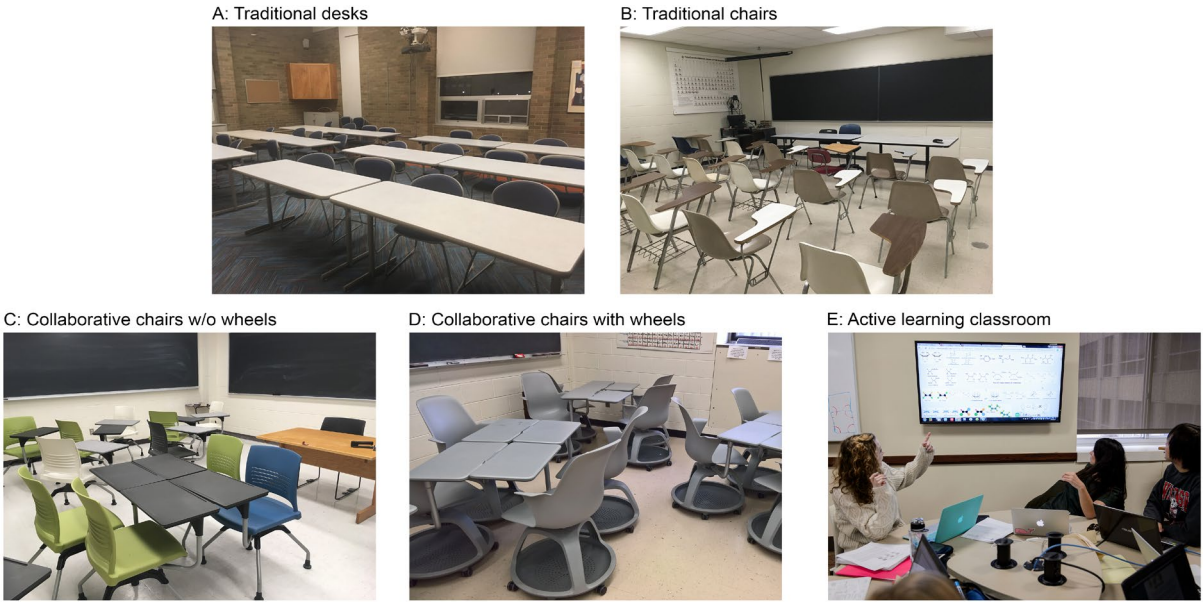

Figure 1. Five classrooms with different furniture.

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It seems logical to assume that active-learning approaches would be most successful if taught in classrooms specifically outfitted with furniture that optimally affords effective collaborative interactions, such as the one shown in Figure 1E. Such classrooms provide group tables with a whiteboard and monitor for each table. This furniture allows students to discuss ideas with each other, jointly attend to and manipulate shared physical and virtual materials, and collaboratively create lists and figures on a whiteboard. Such active learning behaviors have been shown to be more effective at enhancing learning than passive learning behaviors (Chi, 2009).

Yet, little research has investigated whether classroom furniture affects students' learning from collaborative activities. To explore this question, we analyzed data from three active-learning chemistry courses that incorporated collaborative small-group activities in discussion sections. The discussion sections were taught in classrooms with the different types of furniture shown in Figure 1, yielding a natural quasi-experiment.

Theoretical background

In investigating how different types of furniture may affect students' learning in active learning classrooms, we draw on prior research on active learning and affordance theory.

Collaborative activities in active-learning approaches

Undergraduate education focuses not only on teaching content but also on helping students solve challenging problems in the way expert professionals do, which often involves collaboration (Kozma & Russell, 2005; Sfard, 2008). To this end, many undergraduate courses include discussion sections in which students collaborate on challenging activities: "active-learning" approaches (Freeman et al., 2014; Warfa, 2015). We follow Chi's (2009) Interactive-Constructive-Active-Passive (ICAP) framework to define active-learning approaches as instructional methods that engage students in overtly active interactions with learning materials, including discussions among students, joint attention to shared materials, and collaborative manipulation of physical objects. Research on STEM education shows that active-learning approaches lead to higher learning outcomes than traditional instruction (Freeman et al., 2014; Warfa, 2015). In chemistry education, these findings have led to prominent calls to incorporate active-learning approaches; for example, the editor of the *Journal of Chemical Education* argued that: "to put it bluntly, everyone should be taken off the control (i.e., traditional lecture) and switched to the treatment (i.e., carefully considered active-learning methodologies)" (Pienta, 2016, p. 1).

However, research has established that offering collaborative activities does not ensure enhanced learning (Dillenbourg, Baker, Blaye, & O'Malley, 1996). Students often fail to collaborate or engage in ineffective collaborative behaviors (Lou, Abrami, & d'Apollonia, 2001). For example, rather than discussing concepts or jointly manipulating objects, students may split the work (Lou et al., 2001). According to ICAP (Chi, 2009) such suboptimal collaboration behaviors constitute a less active type of behavior and hence reduce learning.

To address issues of ineffective collaborative interactions, many active-learning approaches include support for student collaboration. First, they support collaboration by focusing students' *joint attention* on learning materials. For example, they present worksheets that pose complex problems, following established problem-based learning methods (Lu, Bridges, & Hmelo-Silver, 2014; Oliver-Hoyo, Allen, Hunt, Hutson, & Pitts, 2004) or guided inquiry methods (Chase, Pakhira, & Stains, 2013). To solve such complex problems, students have to help each other by reviewing additional resources (e.g., textbooks, physical models, virtual simulations) and by creating or modifying resources (e.g., drawing). Second, active-learning approaches *facilitate* collaboration by encouraging productive collaboration practices (Chase et al., 2013; Lyon & Lagowski, 2008). Instructors may prompt students to help each other or to reach a consensus before submitting their work (Adesoji & Ibraheem, 2009). Such support may particularly benefit low-performing students who experience collaborative activities as more complex (Kirschner, Paas, & Kirschner, 2010), which can increase cognitive load. These effects can be alleviated by collaboration support (Vogel, Wecker, Kollar, & Fischer, 2017).

Affordances of classroom furniture for collaborative interactions

It seems reasonable to assume that active-learning approaches are more likely to succeed if classroom furniture makes it easy for students to engage in the intended collaborative behaviors. Gibson's theory of affordances (Gibson, 1997) provides a useful lens to investigate the relationship between classroom furniture and collaborative learning. According to Gibson, perception and action are intertwined: we do not "objectively" see objects, but we subjectively see objects as allowing us to take actions that help us achieve goals. That is, we see a chair not just as a chair but as a tool that affords sitting if we are tired or standing on if we need to reach for something. This implies that the affordances of objects around us affect our actions. For example, as chairs typically afford sitting, a party in a room with chairs likely has a different dynamic than a party in a room without chairs.

In applying affordance theory to active-learning approaches, we conjecture that *joint attention* to materials is optimally afforded by classroom furniture that provides space for shared resources. That is, students may be more inclined to review, create, and modify resources together if they have tables that are large enough to lay out materials that can be viewed together and chairs that can be arranged so that all group members can see the materials. Second, *facilitation* of collaboration is optimally afforded by classroom furniture that allows instructors to easily move among student groups and that provides flexibility for instructors to join groups to answer questions or observe students' interactions to intervene if necessary. This does not mean that other classroom furniture does not allow for collaboration support, but it may be less likely to have the intended effect.

Effects of classroom characteristics on students' learning

While we know of no research on effects of specific classroom furniture, few studies have investigated effects of broader classroom characteristics. Most of this research has focused on visual or auditory noise interfering with children's learning (e.g., Fisher, Godwin, & Seltman, 2014). To our knowledge, only two studies have investigated factors of classroom characteristics that included furniture (Barrett, Davies, Zhang, & Barrett, 2015; Barrett, Zhang, Moffat, & Kobbacy, 2013). Barrett and colleagues used data from over 1,000 primary school children and analyzed characteristics of their classrooms with respect to three design principles: naturalness of the classroom (e.g., light, temperature, air quality), individualization (e.g., ownership, flexibility), and stimulation (e.g., complexity). Results showed that—among other factors—classroom flexibility had a positive effect on learning outcomes, explaining 17% of students' academic improvements over the course of a year of instruction. Flexibility described a range of classrooms that allowed for varied instructional activities and varied student needs, such as providing sufficient space to rearrange the classroom. While this research shows that classroom furniture can affect student learning, it does not focus on specific furniture choices or their affordances for active learning. Finally, Kollar, Pilz, and Fischer (2014) found that students have difficulties adapting to classroom designs they are unfamiliar with. However, support for using the new classroom can alleviate these difficulties. However, they did not investigate whether classroom designs afford instructors providing such support.

Research questions and hypotheses

Our brief review of prior research illustrates that we know relatively little about whether and how classroom furniture may affect students' learning from collaborative activities. Addressing these questions is important both from a theoretical and from a practical standpoint. Based on Learning Sciences theory, we expect that affordances of classroom furniture affect students' collaborative interactions, which should in turn affect their learning outcomes. However, we are not aware of empirical research that has examined such effects. From a practical perspective, current moves toward active-learning approaches place new demands on classroom designs. Many classrooms are equipped to facilitate lecture-centric instructional methods and may be suboptimal for collaborative activities. To inform future classroom designs, we need to investigate *whether* such furniture affects students' learning. Further, knowing *how* classroom furniture affects learning may help instructors work around constraints of their classrooms to make the best of suboptimal classroom furniture. Thus, we explore:

Research question 1: Do affordances of classroom furniture affect learning in active-learning courses?

Based on Gibson's (1997) theory of affordances and Chi's (2009) ICAP framework, one might expect that furniture that affords more student interactions over shared resources yields higher learning outcomes. Specifically, traditional-table classrooms (Figure 1A) had large, heavy tables with individual chairs laid out in rows facing a blackboard and screen, affording students attending to the instructor. The tables were large enough for paper-based materials and laptops, but they could not be flexibly rearranged for students to work in groups of different sizes, and the large tables could obstruct the instructor's ability to move around the classroom. While it is still possible for students to work in small groups and for the instructor to walk around to facilitate collaboration, classrooms like the one shown in Figure 1A do not optimally afford joint attention or flexible collaboration facilitation. Therefore, we predicted that traditional-table classrooms would yield the lowest learning outcomes.

Traditional-chair classrooms (Figure 1B) had relatively heavy movable chairs with small, sloped tablet-arms. These chairs could be rearranged to form small groups, but it was difficult for students to reach across the tablet-arms to share materials. Further, the tablet-arms were rather small and barely offered space for a laptop. Hence, they provide limited affordances for joint attention. Therefore, we predicted that traditional-chair classrooms may yield slightly higher learning outcomes than traditional-chair classrooms.

Other rooms had collaborative chairs without wheels (Figure 1C). These chairs were lighter and easy to move. Each chair had a built-in desk that was larger and offered space for a laptop. Further, the chairs could be combined to form small group tables for four to six students, which allowed students to share materials. However, it could be difficult for instructors to move around a classroom with many chairs. Hence, they provided appropriate affordances for joint attention but limited affordances for facilitation. Thus, we predicted that these

rooms may yield higher learning outcomes. A version of these chairs with wheels (Figure 1D) made rearranging the chairs even easier. Hence, we expected higher learning outcomes yet for rooms with these chairs.

Finally, active-learning classrooms with group tables and monitors (Figure 1E) had large group tables, each with a projection monitor and whiteboard, providing sufficient space for laptops and shared resources. Further, the layout of the room was spacious and hence gave instructors enough room to move around to facilitate collaboration. Hence, they provided optimal affordances for joint attention and facilitation. Therefore, we predicted that these rooms would yield the highest learning outcomes.

Further, because low-performing students may particularly benefit from facilitation, we explore:

Research question 2: Does prior performance moderate effects of furniture on learning outcomes?

Finally, to gain insights into the nature of the hypothesized effects, we explore:

Research question 3: How do instructors perceive and compensate for affordances of classroom furniture for collaborative interactions?

We investigate these questions in the context of undergraduate chemistry because chemistry is one of many STEM domains that is currently pushing a move towards active-learning approaches (Pienta, 2016). For example, student groups may be asked to compare the atomic radius of various elements and discuss the underlying factors. Such chemistry activities involve complex problems that require the integration of multiple resources (Bradley et al., 2002). Finally, collaborative activities serve to engage students in problem-solving practices that are prevalent in communities of professional chemists (Kozma & Russell, 2005).

Method

To explore these questions, we used data from three general chemistry courses at a large university in the Midwest U.S. The courses used an active-learning approach, described in the following (see Rau et al., 2017).

Chemistry courses and students

The three courses differed with respect to the target population. *Course A1* is the "default" introductory general chemistry course for students with no special background in chemistry. Most students take this course in their first semester as freshmen. Following this course, students take *Course A2*. *Course B* is the introductory general chemistry course for students with a strong high school chemistry background (two or more years) and placement into at least first semester calculus. This course covers the content of Courses A1 and A2 in one semester. Here, we report on data from Courses A1 and A2 in Spring 2017 (i.e., students in Course A2 were not identical to students in Course A1) and from Course B in Fall 2016. For Course A2, we had access to data from five of six lectures. Altogether, we used data from 2,651 students (136 sections), of whom 618 students (30 sections) were in Course A1, 1,494 students (72 sections) in Course A2, and 539 students (34 sections) in Course B. The sections were taught by 60 teaching assistants (TAs), 13 of whom were TAs in both Fall 2016 and Spring 2017.

All courses involved lectures, labs, and discussion sessions. Lectures were held for the whole course, three times a week for 50 min., led by a professor. Labs were held once a week for 3 hours. Our study focuses on the discussion sessions, which were led by TAs. Courses A1 and A2 had two discussion sessions per week, whereas Course B had one per week, for 50 min. each. Each section had 15-22 students. At the beginning of the Fall semester, all TAs participated in a week-long training that included facilitating group work; there was a refresher session at the beginning of the Spring semester. TAs also attended weekly meetings with the professor. In the discussion sessions, problem-solving activities were done in small groups of three to six students.

Collaborative activities were augmented with several collaboration supports. To enhance *joint attention*, students received worksheets that involved individual and collaborative phases. In individual phases, students worked on tutorials, simulations, or solved problems that introduced concepts. In collaborative phases, students worked in groups on questions that asked them to extend and discuss the concepts they had worked on individually. These collaborative problems were designed to be complex and challenging so that all group members had to contribute to succeed. Worksheets were not graded, but TAs provided oral or written feedback.

TAs took several measures to *facilitate* collaboration. They encouraged students to engage in group discussions. Further, TAs encouraged student groups to use additional resources. For example, they encouraged one student to draw a diagram and encouraged others to label or extend the diagram until everyone understood the topic. At least once in each session, students had to discuss a consensus group answer to a worksheet activity with the TA. If students had questions, TAs did not respond with a direct answer. Instead, they used prompts to draw out students' thinking and helped students generate their own answers.

Classroom furniture

Each discussion section was assigned to one classroom for the semester. Assignment to classrooms was not random; the university's curricular service unit assigns classrooms based on scheduling considerations. Classrooms

varied with respect to furniture as illustrated in Figure 1. Traditional-table classrooms (Figure 1A) had large heavy tables that were difficult to move. They had individual chairs without built-in tablets. Traditional-chair classrooms (Figure 1B), had movable chairs with small tablet arms that could be flipped to open or closed positions. In rooms with collaborative chairs without wheels (Figure 1C), the chairs had large, horizontal workspaces, and chairs could be combined so that the small desks would form small group tables for four, five, or six students, as illustrated in Figure 1C. In rooms with collaborative chairs with wheels (Figure 1D), the chairs could also be combined into small group tables. Moving the chairs was easier because they had wheels. Further, these chairs had a bin under the seat for students to place their backpacks. Finally, active-learning classrooms (Figure 1E) had large group tables with a projection monitor and whiteboard for each table. These classrooms were also equipped with a blackboard and a projector for TAs located in the front of the room. Table 1 shows how many sections of each course were taught in which classrooms.

Table 1: Number of sections (and in parentheses number of students) of the courses by type of classroom

	Course A1	**Course A2**	**Course B**	***Total***
Traditional-table (Figure 1A)		4 (70)	1 (15)	*5 (85)*
Traditional-chair (Figure 1B)	22 (458)	59 (1,240)		*81 (1,698)*
Collaborative chairs without wheels (Figure 1C)	8 (160)	9 (184)	13 (209)	*30 (553)*
Collaborative chairs with wheels (Figure 1D)			4 (66)	*4 (66)*
Active-learning (Figure 1E)			16 (249)	*16 (249)*

Measures

To explore effects of classroom furniture on students' learning outcomes (research question 1), we used students' scores on the final exams of each course, which covered the course content of the entire semester. Final exams were comprised of multiple-choice questions; in all sections of course B and some sections of courses A1 and A2 final exams also included open-ended-response questions. To explore whether prior performance moderates effects of classroom furniture (research question 2), we used students' scores on the first of three midterm exams. To explore how instructors perceive and compensate for affordances of classroom furniture for collaborative interactions (research question 3), we invited TAs to participate in a retrospective survey that contained open-ended questions asking them to "describe how the classroom was organized, what you did, and what the students did" and "how do you think the classroom layout affected students' learning."

Results

We use f for effect sizes. Based on Cohen (1988), $f = .1$ is a small effect, $f = .25$ is medium, and $f = .4$ is large.

Effects of classroom on course grades

To examine the effects of classroom furniture on learning outcomes (research question 1) and moderating effects of prior performance (research question 2), we used a hierarchical linear model (HLM). The model accounted for nested sources of variance due to students being in different sections taught by different TAs. Because the three courses differed in terms of which classroom furniture they used, we used separate HLMs for each course. Each HLM included a random intercept for TAs. Predictors were prior performance, classroom furniture, and an interaction effect between prior performance and furniture. Figure 2 summarizes the findings.

For *Course A1*, there was no significant effect of classroom furniture, $F < 1$, but there was a significant interaction of furniture with prior performance, $F(1, 485) = 3.86$, $p < .05$, $f = .19$. Because the interaction of furniture with the continuous prior performance variable is hard to interpret, we split students into groups of low performing (0-33rd percentile on the first midterm), medium (34th-66th percentile), and high performing (67th-100th percentile), which yields more nuanced insights than common median splits. Post-hoc comparisons showed a marginal effect among students with low ($p < .10$), but not among students with medium or high prior performance (ps > .60). Low-performing students had higher learning outcomes if their discussion section was held in classrooms with collaborative chairs without wheels, compared to traditional-chair classrooms.

For *Course A2*, we found no significant effects (Fs < 1).

For *Course B*, there was a significant main effect of furniture, $F(3, 471) = 4.35$, $p < .01$, $f = .07$, qualified by a significant interaction of furniture with prior performance, $F(3, 527) = 4.35$, $p < .01$, $f = .13$. Post-hoc comparisons showed that the effect of furniture was significant among students with low prior performance ($p < .05$), but not among students with medium or high prior performance (ps > .40). Students with low prior performance had higher learning outcomes if their discussion section was held in active-learning classrooms or in classrooms with collaborative chairs without wheels, compared to classrooms with collaborative chairs with

wheels (*p*s < .01), which were in turn more effective than traditional-table classrooms (*p*s < .01). We found no difference between active-learning classrooms and classrooms with collaborative chairs without wheels.

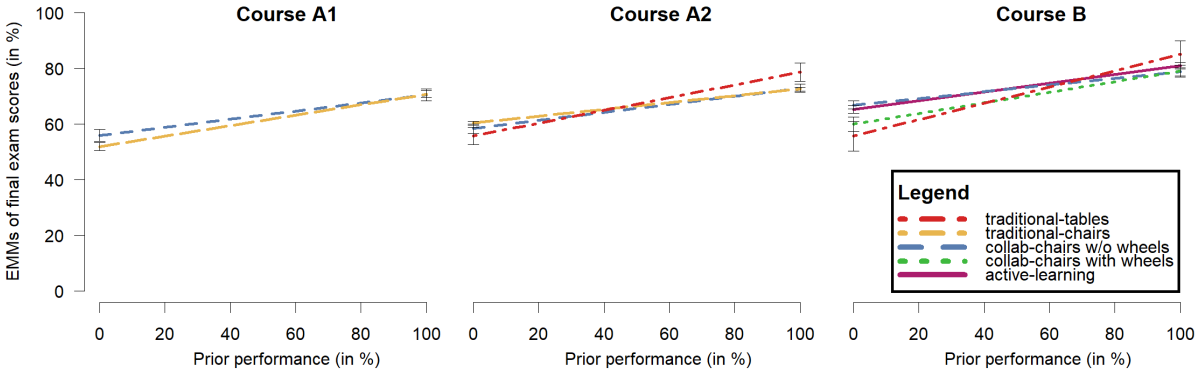

Figure 2. Estimated marginal means (EMMs) and standard errors by course, furniture, and prior performance.

Teaching assistant survey

Of the 62 TAs, 42 answered the survey. We followed Muller's (2014) grounded theory approach to analyze TA responses. We identified several themes that emerged across TAs and across courses. For *traditional-table classrooms*, TAs mentioned that it was difficult to engage students in collaborative interactions altogether, and that students tended to work only with one neighbor at a time. For *traditional-chair classrooms*, several negative themes emerged. First, several TAs described the desks difficult to move, which created noise and "a huge activation energy barrier on them starting their group work." Second, TAs said it was difficult to walk around the classroom to attend to all groups to prompt them to collaborate. Third, TAs commented on the desks being too small for students to lay out multiple resources. Yet, some TAs provided a positive assessment of these classrooms, commenting that they had no difficulties to get students to "turn the chairs around to collaborate." Further, one TA commented that the "advantage of seemingly immobile chairs is that they tend to remain in an organized fashion and can be moved (though a little cumbersomely) if an activity requires team-formation."

For *collaborative chairs without wheels*, two positive themes emerged. First, students were able to form groups easily and flexibly, which facilitated group work. Second, TAs commented that it was easy to switch flexibly between frontal instruction and group work. Two negative themes emerged. First, several TAs felt that the classroom tended to be disorganized because chairs were "jumbled" and "chaotic." Second, TAs commented that students' backpacks were often in the way, which made it difficult for them to move around, amplified by the fact that classrooms were small. For *collaborative chairs with wheels*, the same two positive themes emerged as for collaborative chairs without wheels. In addition, some TAs reported that backpack bins helped create space for themselves to move around to facilitate collaboration. Further, the negative theme of disorganized classrooms emerged more strongly for collaborative chairs with wheels. For example, one TA described: "They are too easy to move. The desks always end up in a jumble and too close together, and before class begins I have to either move the desks myself or make my students move them. I like the standard desks better – it's not that hard for students to stand up to turn their desks." Additionally, TAs commented on space issues if students did not use backpack bins: "Most students did not utilize the trays under the chairs and instead had their backpacks on the floor, which made it really hard for me to move around and answer questions […]. I routinely had to jump over backpacks and move really closely to my student's faces, which was uncomfortable."

For *active-learning classrooms*, all TAs provided positive assessments. They appreciated the space for shared resources and described the furniture as providing "a natural layout for group discussion." One TA provided a negative comment, describing a lack of flexibility to turn to the front because "students situated with their backs facing the board were at a disadvantage as they had to turn to look at the board […]"

Discussion

We used data from a natural quasi-experiment to explore whether affordances of classroom furniture affect learning in active-learning courses, which put a strong emphasis on small-group collaboration. Quantitative analyses of learning outcomes showed that only low-performing students' learning was affected by classroom furniture. Results from courses A1 and B align with hypotheses based on Gibson's (1997) theory of affordances and active learning theory (Chi, 2009) with small to medium effect sizes. For these courses, we found that low-performing students benefitted most from active-learning classrooms that were equipped with furniture that optimally affords both joint attention and collaboration facilitation. These students equally benefitted from collab-

orative chairs that can be arranged into small groups with a shared space, but only for chairs without wheels. While we had not anticipated this finding, it seems to make sense in light of the TA survey, which suggests that the wheels allowed students to move so easily that the chairs cluttered the classroom, which in turn interfered with collaboration facilitation. However, we found evidence for this effect in Course A1, but not in A2. Finally, students benefitted the least from traditional-table classrooms that provide limited affordances for collaboration.

By contrast, we found no effects in Course A2. The finding that low-performing students seem to be most susceptible to effects of classroom furniture offers a potential explanation for the lack of effects in Course A2. Students take Course A2 after Course A1, and the content covered in Course A2 builds on the content of Course A1. Hence, it is possible that students in Course A2 had considerable prior performance as a result of Course A1. On the other hand, students in Course B likely had more prior chemistry experience than students in Courses A1 and A2. An alternative explanation is that students' experience with active-learning methods as a result of having taken Course A1 in the prior semester allowed them to better cope with suboptimal affordances of classroom furniture. Yet another explanation is that TAs in Course A2 might have facilitated collaboration in ways that counteracted negative affordances of classroom furniture. These explanations suggest that instructors should consider how to address potential negative affordances of classroom furniture particularly in introductory courses. As these explanations are post-hoc and tentative they should be examined by future research.

Our qualitative analysis of the open-ended TA surveys corroborates our interpretations in light of the affordances of classroom furniture. TAs agreed that active-learning classrooms had affordances for joint attention to shared resources as well as TA facilitation. With respect to collaborative chairs, it seems that TAs' impressions that classroom clutter interfered with their ability to facilitate group work even more so if the chairs had wheels and students did not remain in a fixed position for the duration of the session. This might explain why collaborative chairs without wheels were more effective than their wheeled counterparts in Courses A1 and B. Further, the TA survey aligns with the interpretation that traditional-chair and traditional-table classrooms provide limited affordances for collaboration. Finally, the survey supports our suggestion that instructional strategies can help TAs overcome potential negative affordances of classroom furniture, such as rearranging chairs and tables and asking students to move their backpacks out of the way or store them in provided areas.

Limitations

Our results should be interpreted in light of several limitations. First, not all courses had sections in all types of classroom, which may limit the generalizability of our findings across courses that include different student populations. Second, even with large samples, causal inferences from quasi-experiments are generally limited because non-random differences between conditions may exist. Hence, future research should test effects of classroom furniture in randomized experiments. Third, we did not conduct classroom observations. Instead, we relied only on survey data from TAs to understand how they managed classroom furniture and how this affected students' collaborative interactions. We therefore do not know to what extent classroom furniture affected the delivery of the active-learning approach. Smaller-scale observational studies as well as surveys of students' experiences could reveal additional affordances of furniture on specific collaborative interactions that we did not identify. Fourth, our TA survey was limited because only about two thirds of the TAs responded. It is possible that TAs with negative experiences were either more or less likely to participate. An observational study could address this limitation. Finally, our study focused on active-learning approaches. Consequently, we do not know whether classroom furniture affects students' benefit from other forms of instruction, and if so, in which way. Future research should investigate whether affordances of classroom furniture align with instructional goals.

Conclusion

Active-learning approaches pose new demands on classroom designs that are often not met. Our findings expand prior research by showing which students benefit most from optimal classroom affordances. The finding that high-performing students are not affected suggests that these students actively engage in effective learning behaviors even when they are not afforded by classroom designs. By contrast, low-performing students benefit from the subtle ways in which the classroom affords joint attention to shared materials. They may also rely more heavily on prompts by instructors, which they are more likely to receive if the classroom affords instructor facilitation. Our findings also have practical implications. First, we found first indications that effects of classroom furniture may apply to introductory courses in particular. Hence, if resources are limited, decision makes may want to invest in redesigning classrooms for introductory courses. Further, we found that instructors can compensate for suboptimal classroom furniture if they are aware of their shortcomings, suggesting they might benefit from training on affordances of classroom furniture. In doing so, they may particularly attend to the needs of low-performing students. In light of the limitations of our study, we hope it inspires future research on how classroom furniture affords student behaviors in ways that may or may not align with instructional goals.

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