Isabel Harris, RICE UNIVERSITY, isabel.harris@rice.edu
Melinda Lanius, AUBURN UNIVERSITY, melinda.lanius@auburn.edu

The Impact of Classroom Architecture and Pedagogical Strategies on University Students' Disruptive Phone Usage in Calculus

ABSTRACT

Personal phone usage—from group messaging to social media scrolling to online window shopping—is widespread in university classrooms. Numerous studies have documented how the presence of cell phones in the undergraduate classroom is more harmful than beneficial. Nevertheless, many educators are reluctant to enact and enforce a phone-free classroom, believing that, as adults, undergraduate students have the right to self-regulate. In this study, we utilize classroom observation data to explore how features of the learning environment, such as classroom architecture and instructor pedagogical strategies, can impact students' propensity to reach for their phones in the middle of a calculus lesson. Further, we use student survey responses to compare overall phone usage to confidence in their knowledge and conceptual understanding of a lesson's primary learning objective. Our results suggest that the learning environment itself, in particular the pedagogical strategies employed and the classroom architecture, can foster self-regulation amongst students without the instructor having to actively enforce a strict no-cell phones policy.

KEYWORDS

mobile phone, texting in the classroom, student learning, pedagogical strategies, classroom architecture

INTRODUCTION

What is the role of smartphones in the classroom? Today's average university student is born into a media-rich world that is unceasingly present in the palm of their hand. While many educators and researchers have shown that computer-based technologies, such as digital games, have a high potential to engage and hold the attention of today's students (Schindler et al. 2017), smartphones—whose primary role is communication and entertainment—are a much trickier teaching and learning tool.

Literature review

Smartphones can be used productively in the university classroom, for example, to facilitate thoughtful activities (Ho 2018) and to collect student feedback (Cline et al. 2018). But researchers have found that most university students using a smartphone during a lesson are using it for distraction rather than to enhance their learning (Ugur and Koc 2015). The impact of smartphones as a university classroom distraction is multifaceted, harming focus, working memory, and efficiency (May and Elder 2018). The presence of one's smartphone in line of sight reduces cognitive capacity, even when the individual is not actively engaging with that device (Ward et al. 2017). The detriments of in-class smartphone use on academic achievement in the university setting are wide-ranging, from a reduction in the quality of lecture notes (Kuznekoff and Titsworth 2013) to a decline in test performance (Lee et al. 2021) and overall grade point average (GPA) (Bellur, Nowak, and Hull 2015). To curb the distraction that smartphones pose to the learning environment, some university instructors have introduced restrictive cell phone policies or total bans in the form of syllabus policies applied to all class sections or grade deductions for noticeable cell phone use (Berry and Westfall 2015). However, enforcing these restrictive policies can be harmful to student-instructor rapport (Flanigan et al. 2023; Hutcheon, Lian, and Richard 2019) and having a restrictive policy may not actually curb students' phone usage (Jones, Aruguete, and Gretlein 2020) or improve students' learning (Lancaster 2018). Further, there is frequently a misalignment between what faculty members and students prefer and perceive as useful in classroom smartphone policies (Stachowski, Hamilton, and Bertram 2020). Some instructors, while still recognizing the potential harm of smartphone distraction, want students to learn to control the impulse to use their phones and make a thoughtful choice about when and how to use a cell phone in the classroom setting, which will be referred to as self-regulating (Neiterman and Zaza 2019).

There is some preliminary evidence that students, when encouraged by their instructor not to use their phones during class, may develop more positive perceptions of their teacher (Lancaster 2018); and that students want the freedom to choose how often they will use their phones, but also want their teacher to support them in making a good decision (Nieterman and Zara 2019). Two strategies researchers have suggested that may help students to self-regulate their in-class smartphone use are 1) to utilize active instructional strategies (Wei, Wang, and Klausner 2012) and 2) to manipulate the classroom layout to keep students in close proximity to the instructor (Petersen and Gorman 2014). Unlike the traditional lecture hall which creates distance between students and instructor, active learning classrooms decentralize the space to create closer distance between students and teacher (Bruner, Affoo, Dietsch 2022).

Research question: Which factors of the learning environment, in particular classroom architecture and instructor pedagogical strategies, impact student smartphone use during a student calculus lab?

Previous studies on student cell phone use in class have utilized student self-reporting (Berry and Westfall 2015). However, this data is unreliable with some participants systematically overestimating or underestimating their use (Hitcham, Jackson, and James 2023). Researchers instead recommend tracking cell phone screen time reports. Yet for some researchers, this style of data collection can be intrusive and can introduce privacy concerns. To address this gap, we propose a novel approach to tracking classroom phone use that allows for a more accurate measure of how much students use their phones while respecting their privacy.

CONTEXT

Study context

This study was planned and conducted by one of the authors, a graduate student, as their first SoTL project with the other author acting as a faculty mentor. The graduate student researcher did not have control over their teaching assignment, classroom assignments, and certain class policies.

Therefore, a research plan that would work in a variety of courses and classrooms was necessary. However, the graduate student did have control over their pedagogical strategies in the course which influenced their decision to focus their research on the latter. The random allocation of classrooms allowed the graduate student to observe different behaviors in architectural spaces. One peer volunteered as the designated observer to minimize inter-observer variability.

We conducted this study within a required supplemental instruction section attached to a large lecture calculus I course. A faculty member taught the large lecture which consisted of two 75-minute meetings a week in a large stadium-style lecture hall. Twice a week, the graduate student researcher led the supplemental instruction sessions of approximately 35 students for 50 minutes with the purpose of reviewing and practicing material covered in the large lecture class. First-year students in various majors such as engineering, building science, and biology typically enrolled in the two supplemental instruction sections in this study.

To minimize burden on students, we used passive and non-intrusive data collection, optimizing the number of students willing to participate in the study. Accordingly, students that opted to participate would be asked to do nothing more than those who opted out.

Pedagogical strategies

We isolated two supplemental instruction sections led by the same graduate teaching assistant (GTA), who had the autonomy to determine the style of instruction, provided that the sessions followed a departmental pacing guide that specified textbook sections to be covered in each lesson. This GTA structured their sections in what we will call a lecture format once a week and a group work format once a week.

Lecture format

In this pedagogical strategy, students took notes over key concepts or practice problems presented by the GTA. To break up the GTA's presentation, students frequently worked on an assigned problem for two to three minutes.

Group work format

In this pedagogical strategy, students worked in groups on a set of problems prepared by the GTA. The GTA circulated around the room to inquire into individual students' thinking and to answer student questions.

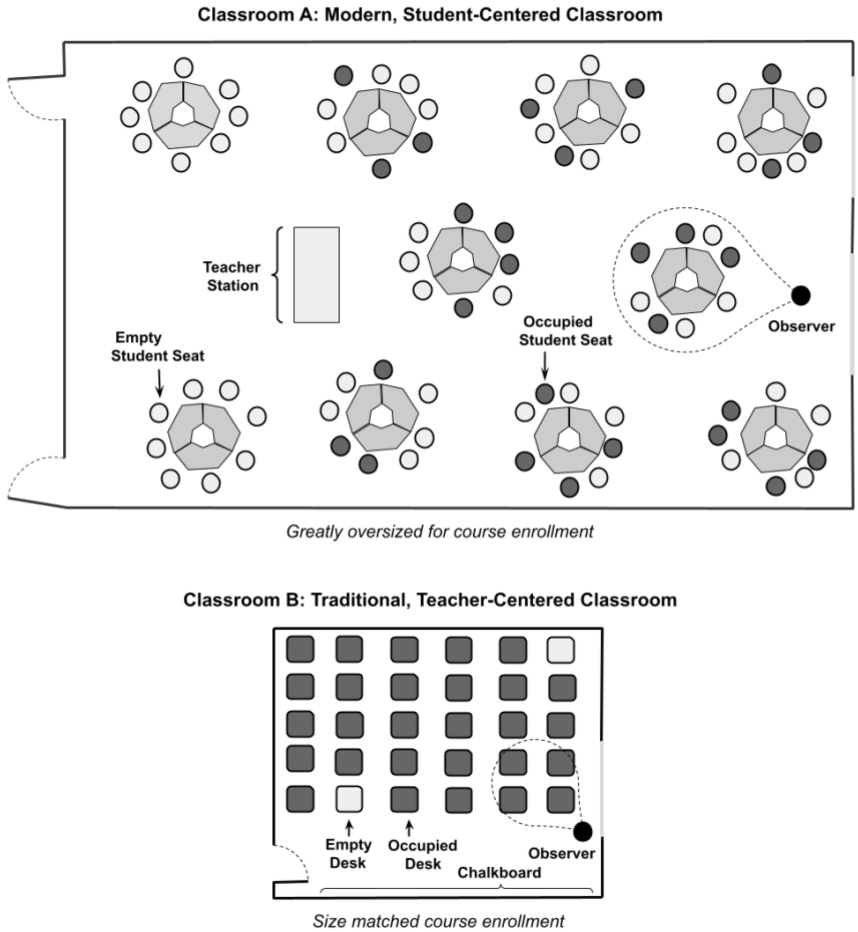
Classroom architecture

The two supplemental instruction sections met in structurally different classrooms (see Figure 1). Key characteristics were 1) the location of the students and instructor in the room and 2) student-instructor proximity.

Classroom A: An oversized, student-centered classroom

Classroom A was a modern, student-centered classroom that had over twice as many chairs as students enrolled. There were movable tables grouped in 10 circles featuring eight caster-wheeled seats each. All four walls featured glass boards and an embedded TV monitor that allowed the instructor to cast from a document camera or central computer. The teacher station-was centrally located with student tables in all directions except behind where the instructor stood. During the lecture format of instruction, students could look at any monitor, which frequently meant the best view students had of the content presentation was away from the GTA. For the group work format, students self-selected their groups of two to six people. The observer selected his location in the room to be in proximity with the students under observation.

Figure 1. Illustrations of the two classrooms utilized for this study



Note: During the lecture format, the instructor would be at the teacher station in classroom A and the chalkboard in classroom B. During group work format, instructor would move throughout the classroom to spend time with each group. Observer changed location to get the best view possible of the participants in each group work section.

Classroom B: An appropriately sized, teacher-centered classroom

Classroom B used a traditional layout proportional to the number of students enrolled. There were approximately 30 desks that all faced the front of the classroom. During the lecture format of instruction, the GTA presented at a chalkboard spanning the front wall. The chairs were movable but not on caster wheels. When in the group work format, students would move their desks to make pods of three to five students. Students could use blackboards on back and side walls of the room to complete the group assignment.

METHODS

Over the past decade, researchers have developed classroom observation protocols to serve a variety of purposes; see Esson et al. (2022) for an overview and discussion of popular options. This type of data collection is non-intrusive for the students and is often a useful, low-cost tool to help SoTL researchers develop hypotheses. However, the existing protocols leave certain aspects of classroom behavior unstudied, including student phone use. With this in mind, we adapted the format of an existing validated protocol, called the Classroom Observation Protocol for Undergraduate STEM (COPUS) in order to isolate the classroom behavior of interest to our study (Smith et al. 2013).

After securing institutional review board approval from Auburn University's Office of Research Compliance (Protocol #22-350 EX 2208), a research team member who was not the instructor of the lab invited all eligible undergraduate students enrolled in either of the GTA's supplemental instruction sections to participate in the study on the first day of class. The research member read a script detailing the purpose of the study, possible risks and benefits, and confidentiality information. They also answered any questions before collecting consent from willing participants. They returned a week later to collect consent from any participants who wanted time to consider. An external observer logged participants' phone use using the observation protocol we developed. At the end of the class period, including the six observation class periods, each student completed a two-question paper survey that served as the attendance credit for the course. Students who did not consent to participate in the study did not have their surveys saved or analyzed. The following subsections further detail these two components of data collection and how we generated a data set for statistical analysis.

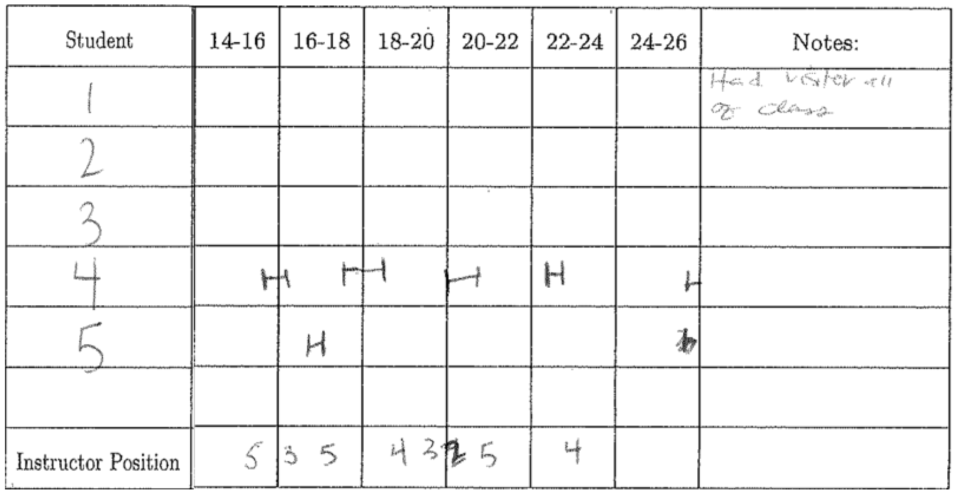
Phone Observation Protocol (POP)

During three weeks of the semester, one research assistant observed four to six students from a group in each section using the Phone Observation Protocol (POP), an observation protocol that we developed for use in this study and that can be found in the supplemental material. The research assistant chose different groups to observe each week, with repeats occurring occasionally. The research assistant would position himself in a location where he felt he had a good view of the students under observation, always choosing a seat that did not obscure the front of the classroom or teacher station. Using POP, the observer identified observed students by a seat number. In two-minute increments, each time the observer sees a student touch their smartphone, they place a tally mark at the approximate time. If the observer witnessed the student using their phones for a prolonged time (not just a touch), the duration of the student's phone use is marked with a horizontal line, as demonstrated in Figure 2. The observer subdivides the entire classroom into regions and records the instructor's position every time they move into another region. Finally, the observer has a column where they can take notes concerning what they have observed. For example, in Figure 2 the observer represented each participant with an anonymous number one through five. For example, the line segment in student 4's row in columns 14–16 represents the beginning of a length of time that student 4 used their phone at the end of the 14–16-minute window of class.

POP use considerations

We developed POP for this study and tested it before use. For the study, we had one observer. He felt that, using POP, he could be very accurate with the time stamps. When observing a group of students with one or two on their phones, the observer felt the protocol worked well and he could include a lot of qualitative information. He could accurately depict the phone usage when three or more students were on their phones at a time, but minimized the notes and comments. In classroom A he would choose a table group to observe and in classroom B he would choose a row or cluster of students to observe.

Figure 2. An example of our Phone Observation Protocol (POP) form



Student	14-16	16-18	18-20	20-22	22-24	24-26	Notes:
1							Had water all of class
2							
3							
4	H	H	H	H	H	H	
5		H					
Instructor Position	5	3 5	4 3	2 5	4		

POP reliability and validity

We did not assess the interrater reliability of POP, however, a single individual conducted all observations for our study to increase the reliability of data collected. To further increase the accuracy of observations conducted with POP, our observer utilized a handheld digital stopwatch to measure the duration of phone use within each two-minute window. Finally, to address validity, the observer only logged information concerning a geographically close cluster of easily observable students.

Quantizing POP data

To generate quantitative data from a POP form, we estimate the culminated observer-created line lengths in units of half-minutes (i.e. filling a quarter of a two-minute window) and count the number of times students touch their phones in class, where a line segment counted as extended phone use or tally mark for a single touch. For example, in Figure 2, we would assign student 4 three and a half minutes on the phone and five phone touches. For our study, the research assistant observed both days of supplemental instruction for the week and followed the same sets of students, when possible, for the lecture and group work formats. The observer did not intentionally mark units in lengths of half-minutes, but this estimation was useful for analysis. Line segments less than one-quarter of a window may be estimated as a half-minute when added with another.

Short survey/exit assignment

At the end of every class period, regardless of whether the observer was present collecting POP data or not, students filled out a short survey as an exit assignment. This survey of a concept check question and a Likert self-evaluation of confidence. The Likert item asks students to evaluate their confidence in understanding the material covered that day, where one indicates little to no confidence and five represents high confidence. While we refer to this data collection as a survey for research purposes, we also designed these ungraded exit assignments with the pedagogical value to students in mind.

Concept checks

For us, a concept check is an open-ended conceptual question that can be answered in one to two sentences given at the end of class and covering the day's material. For example, one session concluded with the concept check: "Explain why the derivative of a constant function is 0." We utilized concept coding (Saldaña 2021) to develop the following ordinal coding scheme, accounting for the variation in students' responses to the concept checks:

1: No answer. The student left the question blank.
2: Rewrote the question. Gave the principle they were asked to explain as an answer.
3: Incorrect attempt.
4: Correct attempt but lacking depth in explanation.
5: Correct attempt with clear and deep explanation.

We scored participants' concept checks using this coding to differentiate between various levels of understanding. In categories three, four, and five, students demonstrated some level of understanding or skills. When calculating demonstration of knowledge in our analysis we kept these differentiations.

STATISTICAL RESULTS

Of the students that consented to participate in the study, 19 attended a class session on a day where the observer was present and were also selected for at least one observation. At random, the observer noted several students' phone usage multiple times during the three-week observation window.

Phone use by pedagogical strategy

To compare students' phone usage between the two pedagogical strategies, we isolated the subset of participants who were observed the same number of times in the lecture and group work formats. Four students appear twice in this subset, and nine students appear once for a total of 17 lecture format data points and 17 group work format data points. The averages and standard deviations of the data by pedagogical strategies are detailed in Table 1. Results of a Wilcoxon Signed-Rank test indicated a small difference in time on phone between the lecture format in any classroom (Mdn = 2, n = 17) and group work format in any classroom *(*Mdn = 1, n = 17), Z = -1, p = .306; however, this difference is not statistically significant.

Table 1. Cross tabulation of phone use by pedagogical strategy and phone use measure

		Pedagogical strategy	
		Lecture	**Group work**
Phone use measure	**Time on phone (minutes)**	M = 3.6 (SD = 4.9)	M = 2.9 (SD = 5.4)
	Touches on phone	M = 3.6 (SD = 6.0)	M = 2.4 (SD = 2.7)

The POP observer noted that some students' phone usage during the group work format was pedagogically productive, for example taking a picture to share work with another student or using a calculator app. POP does not explicitly differentiate between productive and disruptive phone use, and so all measures from POP will include all phone use. This indicates that our reported averages are a conservative estimate of the difference in disruptive phone usage between the two instructional formats.

Phone use by classroom architecture

When comparing students' phone usage based on the two styles of classroom architecture, we grouped observations based on the classroom layout, not taking into account the pedagogical strategy. For classroom A (oversized, student-centered classroom), two students appeared four times in this data set, two students three times, five students twice, and one student once, for a total of 25 data points. For classroom B (appropriately sized, teacher-centered classroom), two students appeared four times in this data set, two students twice, and five students once, for a total of 17 data points. The averages and standard deviations of the data by classroom architecture are detailed in Table 2.

To evaluate whether students' time on their phones and their number of phone touches differed based on classroom architecture, we used Mann-Whitney U tests. The results indicated students in classroom A used their phones a significantly greater amount of time than students in classroom B ($U = 74.5$, $z = 3.52$, $p < .001$). Students in classroom A touched their phones a significantly greater amount of time than students in classroom B as well ($U = 78.5$, $z = 3.52$, $p < .001$).

Table 2. Cross tabulation of phone use by classroom architecture and phone use measure

		Classroom architecture	
		A	**B**
Phone use measure	**Time on phone (minutes)**	M = 5 (SD = 6.1)	M = 0.4 (SD = 0.8)
	Touches on phone	M = 4.3 (SD = 5.3)	M = 0.5 (SD = 1.0)

Phone use by pedagogical strategy and classroom architecture

Starting with the data set we described above to compare phone use by pedagogical strategies, we conducted a cross-tabulation to explore the possible differences in phone use with different classroom architectures and pedagogical strategies, as seen in Table 3 and Table 4.

Table 3. Cross tabulation of time on phone by pedagogical strategy and classroom architecture

		Pedagogical strategy	
		Lecture	**Group work**
Classroom	**A**	M = 5.5 (SD = 5.1)	M = 4.5 (SD = 6.6)
	B	M = 0 (SD = 0)	M = 0.7 (SD = 1.1)

Table 4. Cross tabulation of touches on phone by pedagogical strategy and classroom architecture

		Pedagogical strategy	
		Lecture	**Group work**
Classroom	**A**	M = 5.5 (SD = 6.7)	M = 3.2 (SD = 2.9)
	B	M = 0.2 (SD = 0.4)	M = 0.8 (SD = 1.5)

Classroom B is where the POP observer noted productive student phone usage during the group work format.

Figures 3 and 4 plot the observed values in box and whisker plots where the mean is represented with an "x" and is calculated using data excluding the outliers. When the mean is calculated using outliers, an observed difference remains between behavior in classroom A and classroom B. For example, consider the left box and whisker plot in Figure 4, which shows an outlier in classroom A. Removing this data point and recalculating the average times a student touched their phones during lecture in classroom A yields an average of 3.7. Removing the outliers from the lecture sections in classroom B and touches on phone yields an average of 0. This indicates a stark difference in average phone use exists at the population level, rather than being due to a few outlier students.

Figure 3. Box and whisker plots for time on phone by pedagogical strategy and classroom architecture

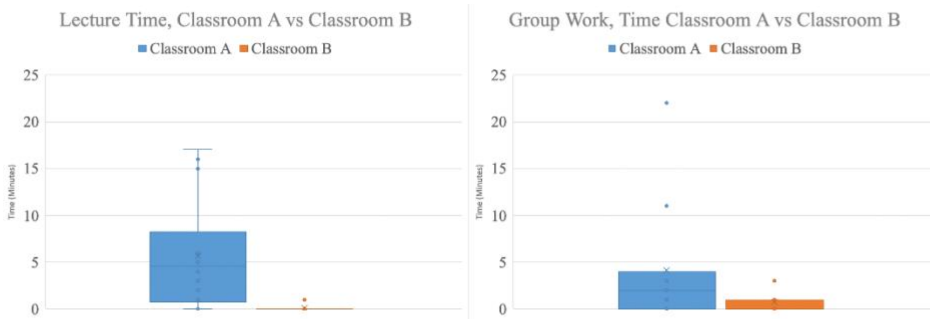
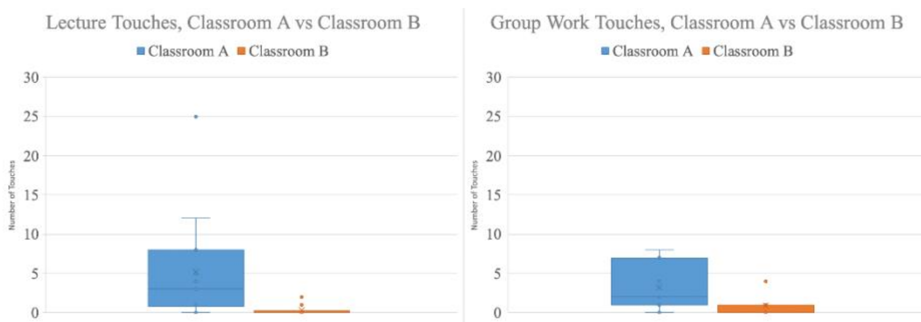


Figure 4. Box and whisker plots for phone use by pedagogical strategy and classroom architecture



Phone use vs academic confidence

We conducted all correlation analyses using SPSS (version 27) 2020. Spearman's rank correlation returns a rho value between –1 and 1, where values close to one indicate a strong positive correlation and values close to negative one indicate a strong negative correlation. We computed a Spearman's rank correlation to assess the relationship between the time students spent on their phones and confidence in that session's material. These results can be seen in Table 5. We found the relationship between time on phone and student confidence to be statistically significant in none of the cases. These results reflect the findings by Deslauriers et al. (2019) that note students learn more in active learning classes but feel like they have learned less.

Table 5. Spearman's rank correlation between the time students spent on their phones and confidence in that session's material

	Correlation coefficient	**p-Value**
All observed classes	$r(40) = .255$	$p = .103$
Lecture	$r(22) = .386$	$p = .062$
Group work	$r(16) = .061$	$p = .811$

We computed a Spearman's rank correlation to assess the relationship between the number of times students touched their phones and their reported confidence in that session's material, as shown in Table 6. We found the relationship between the number of times students touched their phones and student confidence to be statistically significant in the data from all observed classes and lecture style classes, but not in the group work style classes.

Table 6. Spearman's rank correlation between the number of times students touched their phones and confidence in that session's material

	Correlation coefficient	**p-Value**
All observed classes	r(40) = .321	p = .038
Lecture	r(22) = .421	p = .040
Group work	r(16) = .213	p = .397

Phone use vs demonstration of knowledge

We computed a Spearman's rank correlation to assess the relationship between the number of times students touched their phones and their score on the concept check from that session's material, as seen in Table 7. We did not find the relationship between the number of times students touched their phones and student scores to be statistically significant in any cases.

Table 7. Spearman's rank correlation between the number of times students touched their phones and their score on the concept check on that day's material

	Correlation coefficient	**p-Value**
General class	r(40) = -.041	p = .798
Lecture	r(22) = -.136	p = .527
Group work	r(16) = .103	p = .684

We computed a Spearman's rank correlation to assess the relationship between the amount of time students spent on their phones and their score on the concept check from that session's material, as shown in Table 8. The relationship between the time students spent on their phones and student scores was not statistically significant in any case.

Table 8. Spearman's rank correlation between the time students spent on their phones and their score on the concept check on that day's material

	Correlation coefficient	**p-Value**
General class	r(40) = -.148	p = .349
Lecture	r(22) = -.236	p = .267
Group work	r(16) = .013	p = .958

DISCUSSION

Phone use by pedagogical strategy

The results show a non-significant difference between behavior in the lecture style and the group work style lessons. We observed some degree of productive phone use in the group work style lessons. The results show that on average, students choose to use their phones in a disruptive manner marginally less during group work style class. This provides evidence to support Wei's assertion that class formats requiring active participation from students can influence students to stay off their phones (Wei, Wang, and Klausner 2012); however, the difference is not as great as we anticipated given previous the literature.

Phone use by classroom architecture

The results of our analysis show a dramatic difference in student behaviors based on classroom architecture. On average, students in classroom A (the oversized, student-centered classroom) chose to use their phones 14.2 times longer than students in classroom B (the appropriately sized, teacher-centered classroom). Students in classroom A touched their phones on average 8.2 times more than the students in classroom B. While differences in individual students may explain some of this difference in behavior, the starkness of the difference indicates that classroom architecture does have an impact on student choices. Because of the multiple architectural differences in the classrooms, we cannot say if the difference in behavior is necessarily due to proximity to instructor, as suggested by Peterson and Gorman (2014). The difference could be due to the size of the classroom itself, the open space in the classroom, the layout of the seats, or a combination of these factors and more. Space utilization is an important issue for colleges and universities (Fleming et al. 2012). However, due to many factors, such as enrollment fluctuations and building use changes, there is often a mismatch of classroom design and instructional methods. Research into classroom climate with a focus on space was popular in the 1960s–1980s (Wang et al. 2020), before the introduction of mobile devices in the classroom. There is a gap in the research on how classroom mismatch affects student outcomes today. This mirrors other gaps in research, such as the effect of classroom furniture on student performance (Castellucci et al. 2016).

Phone use by pedagogical strategy and classroom architecture

The students, on average, used their phones less during the teaching format that matched the pedagogical strategy the classroom was designed for. Class A used their phones less while working in groups than in lecture style sessions. Conversely, class B used their phones less while in a lecture style session.

Phone use vs. academic confidence

The positive correlation between the time students spent on their phones and their reported confidence in subject knowledge indicates that during the lecture format, students that spent more time on their phones also felt more confident in their knowledge. In contrast, the time a student spent on their phones did not correlate with confidence in group work sessions. Neither of these correlation coefficients were statistically significant at the $p < .05$ level. These positive correlations may be a result of students feeling confident in their knowledge of the material and they, believing they can handle some distraction, chose to use their phones in a disruptive manner. Alternatively, students distracted by their phones could be disengaged from the material; students not fully engaging may not be able to properly estimate their understanding. Student performance does suffer while media multitasking, although students largely underestimate the negative impacts of this behavior (May and Elder 2018).

Phone use vs. demonstration of knowledge

The analysis of the data did not find a relationship between the time students spent on their phones and their conceptual understanding. This differs from results by Wei, Wang, and Klausner (2012), but is likely due to our sampling, which only covered a single concept. Because students may be paying attention during concept A and distracted during concept B somewhat at random, the impact of disruptive phone use on learning is likely only measurable across a broader sample of concepts, such as those measured in a unit exam. Similar results to ours are seen by Jamet et al.

(2020) who found a decrease in student memory but not comprehension after students multitasked for 20 minutes in class.

Breaking down the results between lecture and group work lessons, the results show one correlation is positive while the other is negative, although neither are strong or statistically significant. The slightly positive correlation in group work lessons may be a result of the productive phone use mentioned previously or that the practice problems helped students learn the concept.

CONCLUSIONS

Study limitations

POP had limitations with its capacity and its validity. We tried to curb these limitations through various study design choices. The study also had some limitations that gave us insight into the POP method. The sample size was small (N=19). However, the repeated observation of these students did allow us to gain valuable insight on a small group of students, something not done in previous studies. There was some necessary rounding between the line segments on POP and the tallied time on phones we witnessed from the students. Although there are likely more accurate ways to measure the total time students spent on their phones in class, we liked that POP showed when students were disengaging and what other students or the instructor were doing at the same time.

Capacity of POP

A phone is one of many possible distractions for students. They could also have laptops in class, talk with friends, or think about something else. We chose to use phones as a proxy for focus in our study since, most of the time, phones would not be used productively in this particular calculus class.

Validity of POP

This tool relies on an external observer. This person could miss phone use because of a broken line of sight. Our observer tried to limit this issue by choosing an advantageous location in the classroom for observing the students. They also chose groups of students they could observe with unbroken lines of sight to reduce this issue.

Implications and future directions

Of the two situational factors, classroom architecture had a much greater influence on student phone behavior than pedagogical strategy, which made only a slight difference. Consequently, we recommend colleges and universities carefully consider the learning space when assigning courses to particular classrooms. If an instructor is inadvertently assigned an oversized space and is concerned about disruptive phone use, only utilizing a portion of the classroom to remain in close proximity to their students may positively influence student behavior. Future work will test this conjecture.

The classrooms that students met in differed in both style (student-centered vs teacher-centered) and size (oversized vs appropriately sized). Isolating these differences, as well as the enrollment size, would be interesting future work to determine if one or a combination of these variables impacts students' choices on disruptive phone use in the classroom. Particularly, we would like to further understand the impact of an appropriately sized classroom on student behavior and, if a classroom is appropriately sized, what impact the classroom design (active-learning classroom vs. lecture classroom) has on student behavior.

ACKNOWLEDGMENTS

We appreciate the time and dedication of our POP observer Colby Muir and the helpful comments provided by Haile Gilroy, who read the first draft of our manuscript.

AUTHOR BIOGRAPHIES

Isabel Harris (USA) is a Howard Hughes Medical Institute lecturer in the Department of Mathematics at Rice University. Her research interests include the relationship between classroom architecture, behavior, and calculus readiness.

Melinda Lanius (USA) is an assistant professor of discipline-based education research in the Department of Mathematics & Statistics at Auburn University. Her research interests include undergraduate students' psychological stress in the math classroom and faculty/graduate student teacher professional development.

ETHICS STATEMENT

The authors report no potential conflict of interest. The study obtained institutional review board approval from Auburn University's Office of Research Compliance (Protocol #22-350 EX 2208), and all research participants signed informed consent forms.

REFERENCES

Bellur, Saraswathi, Kristine L. Nowak, and Kyle S. Hull. 2015. "Make it our Time: In Class Multitaskers Have Lower Academic Performance." *Computers in Human Behavior* 53: 63–70. https://doi.org/10.1016/j.chb.2015.06.027.

Berry, Michael J., and Aubrey Westfall. 2015. "Dial D for Distraction: The Making and Breaking of Cell Phone Policies in the College Classroom." *College Teaching* 63 (2): 62–71. https://doi.org/10.1080/87567555.2015.1005040.

Bruner, Justin, Rebecca Affoo, and Angela M. Dietsch. 2022. "Active Learning and Student Achievement: A Matter of Space, Experiences, or Pedagogy?" *Journal of Learning Spaces* 11 (1): 58–78.

Castellucci, Hector I., Pedro M. Arezes, Johan F. M. Molenbroek, Renate de Bruin, and C. Viviani. 2016. "The Influence of School Furniture on Students' Performance and Physical Responses: Results of a Systematic Review." *Ergonomics* 60 (1): 93–110. https://doi:10.1080/00140139.2016.1170889.

Cline, Kelly, Holly Zullo, David A. Huckaby, Christopher Storm, and Ann Stewart. 2018. "Classroom Voting Questions to Stimulate Discussions in Precalculus." *PRIMUS* 28 (5): 438–57. https://doi.org/10.1080/10511970.2017.1388313.

Deslauriers, Louis, Logan S. McCarty, Kelly Miller, Kristina Callaghan, and Greg Kestin. 2019. "Measuring Actual Learning Versus Feeling of Learning in Response to Being Actively Engaged in the Classroom." *Proceedings of the National Academy of Sciences* 116 (39): 19251–7. https://doi.org/10.1073/pnas.1821936116.

Esson, Joan, Paul Wendel, Anna Young, Meredith Frey, and Kathryn Plank. 2022. "Recent Developments in Classroom Observation Protocols for Undergraduate STEM." *Journal of College Science Teaching* 52 (1): 72–82.

Flanigan, Abraham E., Angela M. Hosek, Brandi Frisby, Wayne A. Babchuk, and Emily Ray. 2023. "Student Perceptions of Digital Distraction Prevention and Student-Instructor Rapport." *Communication Education* 72 (3): 217–36. https://doi.org/10.1080/03634523.2022.2149828.

Fleming, Simon, Nathan Apps, Paul Harbon, and Clive Baldock. 2012. "Assessing Space Utilisation Relative to Key Performance Indicators—How Well, Not How Much, Space is Used." *Journal of Higher Education Policy and Management* 34 (5): 503–15. https://doi.org/10.1080/1360080X.2012.715999.

Hitcham, Lucy, Hannah Jackson, and Richard J. E. James. 2023. "The relationship between Smartphone Use and Smartphone Addiction: An examination of Logged and Self-Reported Behavior in a Pre-Registered, Two-Wave Sample." *Computers in Human Behavior* 146: 107822. https://doi.org/10.1016/j.chb.2023.107822.

Ho, Anne M. 2018. “Unlocking Ideas: Using Escape Room Puzzles in a Cryptography Classroom.” *PRIMUS* 28 (9): 835–47. https://doi.org/10.1080/10511970.2018.1453568.
Hutcheon, Thomas G., Aileen Lian, and Anna Richard. 2019. “The Impact of a Technology Ban on Students’ Perceptions and Performance in Introduction to Psychology.” *Teaching of Psychology* 46 (1): 47–54. https://doi.org/10.1177/0098628318816141.
Jamet, Eric, Corentin Gonthier, Salomé Cojean, Tiphaine Colliot, and Séverine Erhel. 2020. “Does Multitasking in the Classroom Affect Learning Outcomes? A Naturalistic Study.” *Computers in Human Behavior* 106: 106264. https://doi.org/10.1016/j.chb.2020.106264.
Jones, Shannise B., Mara S. Aruguete, and Rachel Gretlein. 2020. “Cell Phone Use Policies in the College Classroom: Do They Work?” *Transactions of the Missouri Academy of Science* 48: 5–9. https://doi.org/10.30956/MAS-31R1.
Kuznekoff, Jeffrey H., and Scott Titsworth. 2013. “The Impact of Mobile Phone Usage on Student Learning.” *Communication Education* 62 (3): 233–52. https://doi.org/10.1080/03634523.2013.767917.
Lancaster, Alexander L. 2018. “Student Learning with Permissive and Restrictive Cell Phone Policies: A Classroom Experiment.” *International Journal for the Scholarship of Teaching and Learning* 12 (1): 5.
Lee, Seungyeon, Ian M. McDonough, Jessica S. Mendoza, Mikenzi B. Brasfield, Tasnuva Enam, Catherine Reynolds, and Benjamin C. Pody. 2021. “Cellphone Addiction Explains How Cellphones Impair Learning for Lecture Materials.” *Applied Cognitive Psychology* 35 (1): 123–35. https://doi.org/10.1002/acp.3745.
May, Kaitlyn E., and Anastasia D. Elder. (2018. “Efficient, Helpful, or Distracting? A Literature Review of Media Multitasking in Relation to Academic Performance.” *International Journal of Educational Technology in Higher Education* 15 (1): 1–17. https://doi.org/10.1186/s41239-018-0096-z.
Neiterman, Elena, and Christine Zaza. 2019. “A Mixed Blessing? Students’ and Instructors’ Perspectives about Off-Task Technology Use in the Academic Classroom.” *Canadian Journal for the Scholarship of Teaching and Learning* 10 (1). https://doi.org/10.5206/cjsotl-rcacea.2019.1.8002.
Petersen, Christina I., and Kristen S. Gorman. 2014. “Strategies to Address Common Challenges when Teaching in an Active Learning Classroom.” *New Directions for Teaching and Learning* 137 (2014): 63–70. https://doi.org/10.1002/tl.20086.
Saldaña, Johnny. 2021. *The Coding Manual for Qualitative Researchers*. Sage.
Schindler, Laura A., Gary J. Burkholder, Osama A. Morad, and Craig Marsh. 2017. “Computer-Based Technology and Student Engagement: A Critical Review of the Literature.” *International Journal of Educational Technology in Higher Education* 14(1): 1–28. https://doi.org/10.1186/s41239-017-0063-0.
Smith, Michelle K., Francis H. M. Jones, Sarah L. Gilbert, and Carl E. Wieman. 2013. “The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices.” *CBE—Life Sciences Education* 12(4): 618–27.
Stachowski, Alicia A., Kathryn L. Hamilton, and Andrea M. Bertram. 2020. “Exploring Student and Faculty Reactions to Smartphone Policies in the Classroom.” *International Journal for the Scholarship of Teaching and Learning* 14(1): 11. https://doi.org/10.20429/ijsotl.2020.140111.
Ugur, Naciye G., and Tugba Koc. 2015. “Time for Digital Detox: Misuse of Mobile Technology and Phubbing.” *Procedia-Social and Behavioral Sciences* 195: 1022–31. https://doi.org/10.1016/j.sbspro.2015.06.491.
Wang, Ming-Te, Jessica L. Degol, Jamie Amemiya, Alyssa Parr, and Jiesi Guo. 2020. “Classroom Climate and Children’s Academic and Psychological Wellbeing: A Systematic Review and Meta-Analysis.” *Developmental Review* 57: 100912. https://doi.org/10.1016/j.dr.2020.100912.
Ward, Adrian F., Kristen Duke, Ayelet Gneezy, and Maarten W. Bos. 2017. “Brain Drain: The Mere Presence of One’s Own Smartphone Reduces Available Cognitive Capacity.” *Journal of the Association for Consumer Research* 2 (2): 140–54. http://dx.doi.org/10.1086/691462.
Wei, Fang-Yi F., Y. Ken Wang, and Michael Klausner. 2012. “Rethinking College Students’ Self-Regulation and Sustained Attention: Does Text Messaging During Class Influence Cognitive Learning?” *Communication Education* 61 (3): 185–204. https://doi.org/10.1080/03634523.2012.672755.

APPENDIX

Phone Observation Protocol POP

Technology Observation Protocol for Undergraduates in STEM

Date:

Lecture or Active Learning

Instructions: Indicate which students are under observation by seat number on the corresponding seating chart under the Students Column. In two minute increments, note the time students spend on their phone throughout the course. Additionally, note the general location of the instructor relative to the classroom seating chart. For a lecture day, note which row of students the instructor is closest to during this time. For an active learning day, note which group of students the instructor is working with during that time.
Notice: It is easier to observe students sitting to the side of the observer rather than in front of the observer.

Student	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	Notes:
Instructor Position														

Instructions: Indicate which students are under observation by seat number on the corresponding seating chart under the Students Column. In two minute increments, note the time students spend on their phone throughout the course. Additionally, note the general location of the instructor relative to the classroom seating chart. For a lecture day, note which row of students the instructor is closest to during this time. For an active learning day, note which group of students the instructor is working with during that time.
Notice: It is easier to observe students sitting to the side of the observer rather than in front of the observer.

Student	50-52	52-54	54-56	56-58	58-60	60-62	62-64	64-66	66-68	68-70	70-72	72-75	Notes:
Instructor Position													

Additional Notes: