

Assessing the Use of Spaces Renovated to Support Group Work in an Academic Library

Kimberly A. Rollings
University of Michigan

Jessica Kayongo
University of Notre Dame

This study examined whether three renovated academic library spaces encouraged group work as intended. Hourly observations and a questionnaire documented group work use, space preferences, and suggested improvements. Compared to the three renovated spaces, significantly more group work occurred in an unrenovated space that was more open, spacious, and visible. Questionnaire results indicated that noise levels, available space and furniture, lighting quality, location, and operating hours also influenced group work space preferences. Suggested improvements included designated quiet and talkative areas, reservable space, and additional tables. Findings offer insights to inform future library group work space research, design, and evaluation.

Introduction

Contemporary library design has evolved in response to changing user needs, including on college campuses. Technological advancements, increasing availability of and demand for electronic versus print resources, competition from other information providers, such as Google, sustainability awareness, and a need for social spaces have driven this evolution (Latimer, 2010; McKay & Buchanan, 2014). Recent academic library design trends have also responded to shifts in pedagogy and learning paradigms focused on shared knowledge and project- and team-based learning (Ojennus & Watts, 2017). These evolving technologies and educational approaches require more resources and spaces that support collaboration, social activity, and formal and informal learning in addition to spaces for individual activity (Beckers et al., 2015; Bennett, 2009; Kim et al., 2021; Montgomery & Miller, 2013; Yoo-Lee et al., 2013). Libraries have adapted by repurposing spaces--originally intended for printed materials and individual work-- for students and group work (Bryant et al., 2009; Crook & Mitchell, 2012; Harrop & Turpin, 2013; Holder & Lange, 2014). These space transformations, however, are not always successful. For example, spaces redesigned to support group work may instead be used more for individual work (Bryant et al., 2009; Crook & Mitchell, 2012; Harrop & Turpin, 2013; Holder & Lange, 2014). As universities continue to convert printed material storage and

individual work spaces into spaces for more group work, understanding how renovations support these new functions is critical (Kim et al., 2021).

The design of academic library spaces influences where students conduct individual and group work (Waxman et al., 2007). Group work space design in academic libraries, however, is not as well understood as the design of traditional library spaces for individual study (McKay & Buchanan, 2014). Group and individual users have different spatial needs that require a variety of appropriately supportive spaces (Kim et al., 2021). Appropriate spatial layout, acoustic and visual privacy levels, and noise levels vary based on individual or group task type and complexity, among other factors (Chacon Vega et al., 2020; Hoendervanger et al., 2019; Kang et al., 2017; Kim et al., 2021). Additional research is needed to understand how architectural design characteristics, such as openness, may encourage or inhibit group work within academic library settings and inform successful design and redesign of group work spaces in academic library settings (Given & Leckie, 2003; Kim et al., 2021).

Group Work Space Design and User Behavior

While the transformation of academic library spaces has been well-documented (e.g., Bennett, 2009; Ozburn et al., 2020), our understanding of the design characteristics that support group work within these settings is incomplete (Kim et al., 2021). Prior studies of academic library group work spaces established the importance of amenities and resources; power outlet availability; computers and technology; building hours and access; noise and lighting levels; furniture variety; study area quantity, quality, variety, size, and spatial organization; and general aesthetics

Kimberly A. Rollings is a Health and Design Research Fellow at the Institute for Healthcare Policy & Innovation, University of Michigan.

Jessica Kayongo is the Global Affairs and Sociology Librarian, University of Notre Dame.

(Bailin, 2011; Bryant et al., 2009; Holder & Lange, 2014; Latimer, 2010; Lawrence & Weber, 2012; Ojennus & Watts, 2017; Vaska et al., 2009). Other work underscored the need for furnishings and amenities conducive to social space and interaction, including large tables for group work, comfortable furniture, access to food and a café-like atmosphere, and varying levels of background noise and ambience, as well as computers, power outlets, and other technological resources needed to support group work (Montgomery, 2014; Ojennus & Watts, 2017). With few exceptions, prior work largely focuses on resources (outlets, Wi-Fi connection, whiteboards), furnishings, and indoor environmental qualities (noise, lighting) without examining more architectural design characteristics. Workplace literature, for example, addressed how spatial openness, enclosure, and visibility affected individual and group work space preferences, satisfaction, and productivity (Kim et al., 2021; Ojennus & Watts, 2017). Library design and renovation teams require evidence-based knowledge of these concepts within academic library settings to create successful group work spaces. The following sections describe how the design characteristics of openness, enclosure, and visibility affect user behavior, especially related to control and noise.

Openness, Enclosure, and Visibility

In addition to resource availability, the openness, enclosure, and visibility of a space plausibly affects college students' selection of individual and group work spaces within academic libraries based on studies in other settings. The workplace literature previously defined openness as a proportion of total floor area to interior wall and partition length, and differentiated this measure from the degree of enclosure which takes into account wall and partition height (Hua et al., 2010). Openness also affects the distance between people in a space. Short distances between individuals or groups of people was associated with increased sensory input, such as noise and other distractions, and affected productivity and spatial preferences in several studies (Haapakangas et al., 2017; Kim et al., 2021). Workplace literature reported that individuals tended to prefer greater distances between people, while proximity to others in a group setting encourages interaction (Hua et al., 2010; Kim et al., 2021).

Workplace and environmental psychology literature reported that more open and less enclosed spaces that support social activity are also often associated with more visibility (Kim et al., 2021). Visibility is the degree to which people can see and are seen by people (Evans & McCoy, 1998). A three-walled "nook" or semi-enclosed area illustrates these three design characteristics. Nooks are thought to aid group members in creating a sense of territory so they can better control interactions and distractions while

working (Taylor, 1988). Similarly, mobile technology and other items, such as white boards on wheels, can be used to create enclosure or open up a space (Graetz & Goliber, 2002). The degree of enclosure affects both visual and auditory privacy such that totally enclosed spaces without windows omit visibility and noise while discouraging others from joining.

Library literature also documented the need for a variety of and the separation of social from quiet spaces (e.g., Kim et al., 2021; Latimer, 2010; Ludwig, 2010). This variety of spaces ranges from fully enclosed, private individual and group study rooms with four walls and a door to large, open, spacious, and visible reading rooms and study areas for numerous individuals or groups. One study found that the renovation of a library study area to provide a "defined yet open" scheme, in addition to more power outlets, better lighting, and aesthetics, dramatically increased use and improved user satisfaction (Fox & Doshi, 2013). The openness, degree of enclosure, and visibility likely contributed to these results. Open, interactive, and versatile group work spaces remain a high priority in academic library space design (e.g., Head, 2016).

Control

A variety of space sizes and layouts with differing levels of openness, enclosure, and visibility — including separate social group meeting and quiet individual work spaces — is thought to affect space preferences and behavior by providing users with a sense of control over their social interaction (Evans & McCoy, 1998; Greenbie, 1981; Zimring, 1982). In this context, control is defined as the ability of a user to alter their environment and regulate their exposure to surroundings (Evans & McCoy, 1998). Offering a choice, but not an overwhelming abundance, of available workspaces enabled control and led to more productivity and creativity in several studies (Clements-Croome, 2015; Iyengar & Lepper, 2000; Kim et al., 2021). An environment that enables control for all users offers gathering spaces for individuals and groups, including spaces that enable control of visual and auditory privacy and exposure to noise (Clements-Croome, 2015; Congdon et al., 2014).

Adaptable spaces have also been found to facilitate control by enabling comfortable engagement among collaborating group members (Gisolfi, 2018; Sinclair, 2007). Movable furniture encourages interaction, allowing users to adjust their interpersonal distances (Evans & McCoy, 1998; Sinclair, 2007). Movable whiteboards or partitions also enable further control of visual privacy and distraction (Sinclair, 2007). Adjustable lighting and other design features such as window views further contribute to perceptions of control (Evans & McCoy, 1998), which can be difficult in spaces initially designed to house printed material shelving and

later converted into spaces for individual and group work (Burton & Kattau, 2013; Vaska et al., 2009). The original lighting and spatial design were not intended to support these activities or students' constant staring at digital screens (Ojennus & Watts, 2017). Providing adaptable spaces for different users is also necessary as space is a limited resource within academic libraries and on college campuses. Enabling users to select appropriate spatial layouts, furnishings, acoustic and visual privacy, lighting levels, and noise levels depending on their tasks is necessary for satisfaction and productivity (Kim et al., 2021).

Noise

Different levels of noise, ranging from silent to ambient to talkative, are desired depending on task complexity and whether conducting individual or group work (Ojennus & Watts, 2017). Ambient or "background" noise, rather than silence, can provide a sense of sociability in a space and help people feel comfortable conversing in groups (Cornell, 2002; Lange et al., 2016). For example, college students surveyed about their library experience expressed a desire for ambient noise and stated that, "It's depressing when totally silent," "I like ambient noise," "It's too quiet and intense, and, "[It's] much easier to study in a more laid-back environment" (Lange et al., 2016, p. 55). Low or no background noise levels can prompt people to be quieter, while background noise promotes interaction that is especially helpful for encouraging group work (Kim et al., 2021). Appropriate levels of sound are thought to connect collaborating group members with each other, the larger community, and physical space (Gisolfi, 2018; Montgomery & Miller, 2013; Revill, 2014). Group members who feel comfortable talking are more likely to have more productive sessions because they do not feel they have to whisper or restrain productive conversation (Lange et al., 2016). Additionally, several studies reported that some individual library users also found social spaces conducive to work because of the ambient noise and presence of others working (Bennett, 2007; Montgomery, 2014; Ojennus & Watts, 2017; Yoo-Lee et al., 2013). However, one study noted that students wanting quiet, individual study space requested separation from spaces for group and social activity with ambient noise (Ojennus & Watts, 2017). General study spaces intended for conversation within an academic library often need to specify acceptable noise levels in various spaces, and supply background noise in silent spaces where group interaction is invited while noting that individual use may be discouraged by such measures.

Research Questions and Hypotheses

The present study aimed to address whether library renovations did or did not support group work as intended,

gather student preferences for and suggested improvements to library group work spaces, and inform future research, design, and evaluation of library group work spaces more broadly. The study explored whether four spaces of varying openness, enclosure, and visibility levels within an academic library – three renovated and one unrenovated – supported group work as intended. The research questions were:

- 1.1. Do amounts of total, individual, and group work conducted in each space significantly differ?
- 1.2. In what space is group work completed the most?
- 2.1. Where do users of these spaces prefer to conduct group work on campus and why?
- 2.2. What changes would students make to library spaces to support group work?

Method

Study Site and Observed Spaces

The University of Notre Dame, a small private university in South Bend, Indiana, serves approximately 12,600 students (8,600 undergraduate and 4,000 graduate students) enrolled in four colleges and three professional schools. The campus also houses numerous research institutes and centers. The main campus library, Hesburgh Library, was built in 1963 to store printed materials and provide space for individual students to quietly read and conduct research. Changes in academic library design trends and higher education pedagogies led to numerous renovations within the last decade that reduced printed resources and introduced a café, more electronic and technological resources, and numerous student areas for both quiet individual and interactive group work.

Library renovations included transforming three spaces on the first and second floors that were originally used for printed material storage and individual work. Renovations aimed to increase spaces for group and individual work. A variety of stationary and movable chairs and tables, power outlets, white boards, and enclosed group study rooms were added as part of the renovations. This study observed four spaces: one unrenovated space for comparison, and the three renovated spaces: the Grand Reading Room or "Fishbowl," Research Commons, 1st-Floor Collaboration Hub, and 2nd-Floor Collaboration Hub. Figure 1 displays the floor plans of each space.

Figure 2 displays a photo of each space and describes the pre-renovation use and post renovation intent, design attributes (size, openness, enclosure, visibility, distance between seating arrangements, furniture types, and available control, resources, and views), and a rank from one (most) to four (least) comparing several design attributes (size, openness, enclosure, visibility, and distance) across the four observed spaces. Attributes that were constant across

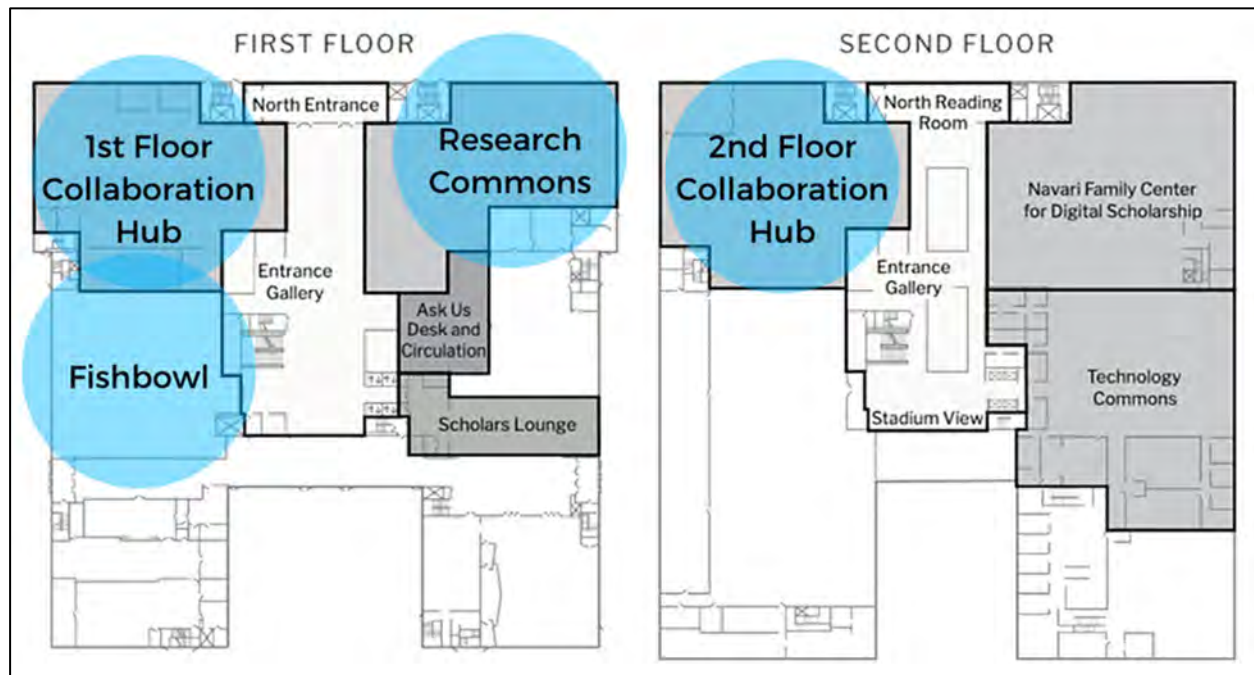


Figure 1. First and Second Floor Library Study Space Locations

Note: Arrows = entrances. Blue circle = one of four observed study spaces: The Research Commons and 1st- and 2nd-Floor Collaboration Hubs were renovated. The Fishbowl was unrenovated.

all four spaces were excluded from Figure 2. Expected noise levels were not designated in any space. Wall and floor materials and colors, type of window view, and lighting were similar across all spaces. With the exception of the 2nd-Floor Collaboration Hub study nooks and enclosed study spaces, all spaces had 12-foot ceiling heights. Ceiling lighting was on at all times and not adjustable by users in any space. However, the unrenovated Fishbowl contained discontinuous fluorescent ceiling fixtures, while the renovated spaces provided full spectrum ceiling track lighting directed towards the ceiling to evenly diffuse light and avoid shadows and contrast on work tables. Exterior window blinds were available and could be raised or lowered by occupants. No interior nature (plants, images of nature, or water features) was present in any space.

The unrenovated Fishbowl (Figure 2a) was the most open, most visible, and least enclosed space observed, and had the largest amount of space between seating arrangements. The space was easily accessed from the entrance lobby and was visible from a main campus-facing library entrance hallway. Various furniture types and group arrangements included stationary tables and chairs, high-backed “booths,” and sofa-like chairs. Floor-to-ceiling windows facing the exterior and interior of the building along two walls made the space highly visible within and outside of the space. Students could use movable white boards and rearrange furniture to



create larger seating arrangements, although tables and chairs did not have wheels.

The renovated Research Commons (Figure 2b) was the second most open space, second most visible, and slightly more enclosed than the Fishbowl. Located diagonally across the main lobby from the Fishbowl, the space was only visible upon entering or from outdoors. Furniture included wheeled tables with stationary chairs, sofa-like chairs, and a sofa. Two semi-enclosed seating “nooks” with movable white boards were also available. Library staff offices with glass walls surrounded the Research Commons along one full wall and part of two additional walls.



Although the renovated 1st-Floor Collaboration Hub (Figure 2c) was the largest space overall, the space contained several smaller, reservable, and fully enclosed spaces surrounded by several smaller narrow spaces for various furniture arrangements. This layout rendered the space less open, more enclosed, and less visible than other spaces observed. In addition to numerous low tables with sofa-like chairs and a few individual study booths, rows of wheeled office chairs and tables of various sizes lined three walls with little space for rearranging.

The renovated 2nd-Floor Collaboration Hub (Figure 2d) consisted of seven semi-enclosed “nooks” with a stationary table, movable chairs, and fixed white boards. Each nook contained a dropped ceiling and ceiling light fixture. Other enclosed group study spaces available for reservation in this

Figures 2a and 2b. Photos and Descriptions of the Two Observed Library Spaces

a. Fishbowl (unrenovated)	Rank	Attribute	Description
<p>Pre-renovation use: Individual and group work Post-renovation intent: N/A (unrenovated)</p> 	2	<i>Size</i>	- 10,400 SF 8 zones 159 seats (largest space)
	1	<i>Openness</i>	- Most open
	4	<i>Enclosure</i>	- Least enclosed space; not surrounded by offices or enclosed study spaces
	1	<i>Visibility</i>	- Most visible within the space, and from the entrance hallway and exterior
	1	<i>Distance</i>	- Most space between seating arrangements, enabling furniture rearranging
	<i>Furniture</i>	- 13 stationary tables/4-6 chairs (some pushed together with 9-10 seats), 4 tables/4 chairs, 3 high-backed booths, 10 varied arrangements of upholstered, sofa-like chairs (1 sofa) and tables, 2 curved seating arrangements (e.g., for presentations)	
	<i>Control</i>		- Users move chairs and tables even though not wheeled; low auditory and visual privacy
	<i>Resources</i>	- Outlets, movable whiteboards, Wi-Fi	
	<i>Views</i>		- Floor-to-ceiling windows on 2 walls (1 exterior, 1 interior)
	b. Research Commons (renovated)	Rank	Attribute
<p>Pre-renovation use: Printed material storage Post-renovation intent: Mostly quiet individual work</p> 	3	<i>Size</i>	- 9,575 SF 6 zones 87 seats
	2	<i>Openness</i>	- Open arrangement and 2 small seating nooks
	3	<i>Enclosure</i>	- Surrounded by 3 walls (1 with exterior windows, 2 with glass office walls)
	2	<i>Visibility</i>	- Visible from within and outdoors (2 semi-enclosed nooks for 4-6 people with little visibility)
	2	<i>Distance</i>	- Seating arrangements are closer together than in the Fishbowl
	<i>Furniture</i>	- 10 stationary tables that seat 4-6 people; coffee tables with upholstered comfy chairs; 1 sofa; 2 nooks with 1-2 tables with 4-8 seats each and a mobile white board	
	<i>Control</i>		- Stationary tables/chairs; movable whiteboards available; little privacy
	<i>Resources</i>	- Outlets, movable whiteboards, Wi-Fi	
	<i>Views</i>		- Floor-to-ceiling windows on 1 exterior wall; interior office glass walls on 2 sides

Figures 2c and 2d. Photos and Descriptions of the Two Observed Library Spaces

c. 1 st -Floor Collaboration Hub (renovated)		Rank*	Attribute	Description
<p>Pre-renovation use: Individual and group work Post-renovation intent: Group work</p> 	1 (4)	Size	- 11,500 SF including group rooms and classroom 7 zones 202 seats (118 in open areas)	
	3 (4)	Openness	- Open but narrow spaces compared to the Fishbowl (<i>with fully enclosed group rooms</i>)	
	3 (1)	Enclosure	- Open but long, narrow spaces (<i>10 fully enclosed, reservable group rooms and 1 classroom</i>)	
	3 (n/a)	Visibility	- Limited visibility within/outside the space due to narrow open and the enclosed spaces	
	3 (n/a)	Distance	- Furniture arrangements are close together and to walls, with little space for rearranging	
		Furniture	- Rows of 6 wheeled tables/6-8 wheeled chairs; 13 tables/4-6 chairs; 7 low tables/2-4 sofa-like chairs; 1 table/2 chairs, 4 individual study booths; other moveable chairs (<i>group rooms: table/6-7 chairs; classroom 5 tables/4 chairs</i>)	
		Control	- Movable chairs/tables, but little space or privacy (<i>group rooms: high visual/auditory privacy</i>)	
		Resources	- Outlets, movable whiteboards, mobile TVs, Wi-Fi (<i>group rooms: white boards</i>)	
		Views	- Exterior windows on 2 sides (<i>group rooms: some glass walls or panels in doors</i>)	
	d. 2 nd -Floor Collaboration Hub Nooks (renovated)		Rank	Attribute
<p>Pre-renovation use: Book shelving Post-renovation intent: Group work</p> 	4	Size	- 7 nooks, 5 chairs each (35 seats)	
	3	Openness	- Somewhat open	
	2	Enclosure	- 3-sided enclosure with a dropped ceiling	
	3	Visibility	- Limited visibility from within the space due to 3-sided enclosure	
	n/a	Distance	- n/a, seating is separated from other arrangements	
		Furniture	- Each of 7 nooks has stationary tables with 4-5 wheeled chairs	
		Control	- Movable seating; bright but not adjustable overhead lighting; some visual privacy	
		Resources	- Outlets, 1-3 fixed whiteboards/walls, mobile TVs, WiFi	
		Views	- None	

Notes: SF = square feet; ranks range from 1=most to 4=least.

* = 1st-Floor Collaboration Hub rank values in parentheses refer to the fully enclosed group study rooms and classroom.

area were excluded from the study due to limited library staff time for observation. Semi-enclosed nooks and fully-enclosed study rooms in both Collaboration Hubs contained no windows, but some had glass walls or a panel in the door for safety and surveillance.

Procedures

Data Collection

Observation. Student library workers, who were unaware of the study purpose, were trained and provided the same directions (Figure S1, Supplementary Material). On seven consecutive days (Sunday-Saturday) during each staffed hour of operation, one trained observer walked through each space with a clipboard and detailed floor plans (Figure S2, Supplementary Material). Counts of individual and group workers, hour and day, and group size were systematically documented for each space. Using the floor plans, observers marked where people appeared to work individually or in groups. Individual work was described as a student looking at his or her laptop, books, or papers without conversing with others about the work. Group work was defined as one or more students sharing views of laptops, books, or papers while conversing aloud about the work in front of them. Each group of people working together was circled, then later counted to calculate group size.

Questionnaire. A brief four-item questionnaire (Figure S3, Supplementary Material), developed by the research team and approved by library staff, documented students' preferences and suggested improvements for group work spaces. Students noted their level (undergraduate or graduate student); where they prefer to study and why (e.g., hours, availability, amount of space, ambience, food availability, lighting, noise, furniture, location, resources, or other factors); and suggested changes to library spaces to support group work. During a two-week period, a total of 300 (50 each) questionnaire copies were placed on tables in each of the four study spaces and at each of two main entrance doors. Submission boxes placed by entrances displayed brief instructions for completing and submitting the questionnaires.

Data Analysis

Observation. Manually recorded individual and group work counts, observation hour and day, number of groups, and group size within each space were digitized and error-checked by research assistants. Using Stata/SE (version 17.0), counts of total, individual, and group work in each of the four spaces were calculated. The percentage of group work (group count divided by total count) in each space was also calculated as that measure could affect anecdotal

observations of group work quantity shared by library staff. Minimum, maximum, and average group size (group count divided by the number of groups) were also calculated for each space. Three negative binomial regression models examined associations between space and total, individual, and group work count data, adjusting for day and time. Negative binomial regressions were appropriate for the dependent, non-normally distributed count variables (total, individual, and group). A two-part model, however, was necessary to analyze the group work percentage (group divided by total count) dependent variable that contained numerous zero values. A logit model estimated the binary outcome (whether group work percentage was zero or positive) in part one, while a generalized linear model estimated the continuous outcome (conditional on positive group work percentages) in part two (Belotti et al., 2015). All models were adjusted for day and time as operating hours and student library use varied across day of the week and time of day relating to weekly deadlines and class schedules.

Questionnaire. Paper questionnaire responses were digitized and systematically coded by two researchers to aggregate similar responses and identify common themes. Coding differences were discussed until consensus was reached. Using Microsoft Excel, descriptive statistics were calculated: the number of undergraduate and graduate student respondents; location preferences for group work within Hesburgh Library and on campus; factors influencing group work location preferences; and suggested changes to Hesburgh Library group work spaces.

Results

Observation Results

RQ 1.1: Variations in total, individual, and group work among the four study spaces

A total of 376 walk-throughs (94 per space) were completed. Table 1 descriptively reports observed work counts, average work counts and group work percentage, and average group size within and across all four spaces. A total of 9,014 counts were recorded (5,845 individual, 3,169 group). On average, 31% of work counts reflected group work. The average group size was 3 people, ranging from 2 to 10 people per group. Ten-person groups were observed in the 1st-Floor Collaboration Hub and Fishbowl spaces.

Table 2 presents results from adjusted negative binomial models that examined associations between space and total, individual, and hourly group work counts, adjusted for day and time. Beta coefficients reflect the expected difference in log count (degree of change) between each renovated space and the unrenovated Fishbowl (reference group) when day and time remain constant. To facilitate interpretation, beta coefficients were exponentiated to produce Incident Rate

Table 1. Unadjusted Overall and Average Total, Individual, and Group Work Counts, Group Work Percentage, and Group Size by Space								
Space	Overall Work Counts (n=376)			Average Work Counts and Group Percentage [Mean (SD), Range]				Average Group Size (min-max)
	Total	Individual	Group	Total	Individual	Group	Group Percentage	
Fishbowl	2280	1204	1076	24.2 (15.0), 0-59	12.8 (8.9), 0-41	11.4 (10.1), 0-44	40.9% (26.6), 0-100%	2.9 (2-10)
Research Commons	1361	1056	305	14.5 (8.2), 0-32	11.2 (6.8), 0-27	3.2 (4.5), 0-22	19.2% (21.4), 0-77.3%	2.5 (2-6)
1st-Floor Collaboration Hub	4406	3001	1405	46.9 (25.1), 2-97	31.9 (17.3), 2-71	14.9 (12.8), 0-47	27.3% (19.3), 0-73.7%	2.8 (2-10)
2nd-Floor Collaboration Hub	967	584	383	10.3 (4.4), 1-21	6.2 (4.1), 0-18	4.1 (3.8), 0-16	36.4% (29.8), 0-100%	2.6 (2-4)
Total	9014	5845	3169	24.0 (20.8), 0-97	15.5 (14.3), 0-71	8.42 (9.9), 0-47	30.9% (25.9), 0-100%	2.8 (2-3) people

Table 2. Negative Binomial Regression Model Results Predicting Total, Individual, and Group Work Counts by Space, Adjusting for Day and Time

Space	Total Work Count (n= 376)				Individual Work Count (n= 376)				Group Work Count (n= 376)			
	Coef. (SE)	IRR (SE)	p-value	95% CI	Coef. (SE)	IRR (SE)	p-value	95% CI	Coef. (SE)	IRR (SE)	p-value	95% CI
Fishbowl	--	--	--	--	--	--	--	--	--	--	--	--
Research Commons	-.51 (.04)	.60 (.03)	<.001	[.55, .65]	-.13 (.05)	.88 (.05)	.013	[.79, .97]	-1.36 (.12)	.26 (.03)	<.001	[.20, .33]
1st-Floor Collaboration Hub	.66 (.04)	1.94 (.07)	<.001	[1.80, 2.08]	.92 (.05)	2.51 (.12)	<.001	[2.29, 2.75]	.18 (.11)	1.20 (.13)	.103	[.96, 1.48]
2nd-Floor Collaboration Hub	-.83 (.05)	.44 (.02)	<.001	[.40, .48]	-.71 (.06)	.49 (.03)	<.001	[.44, .55]	-1.04 (.12)	.35 (.04)	<.001	[.28, .45]

Table 3. Two-Part Model Results Predicting Group Work Percentage by Space, Adjusting for Weekday and Time

Space	First part: Logit (n= 355)			Second part: GLM (n= 279)			Average Adjusted Predictions	
	AOR (SE)	p-value	95% CI	Coef. (SE)	p-value	95% CI	Mean (SD)	95% CI
Fishbowl (<i>reference</i>)	--	--	--	--	--	--	40.7% (2.1)	[36.6%, 44.7%]
Research Commons	.07 (.03)	<.001	[.02, .18]	-.17 (.03)	<.001	[-.22, -.11]	17.9% (1.8)	[14.3%, 21.4%]
1st-Floor Collaboration Hub	.48 (.24)	.146	[.18, 1.29]	-.14 (.03)	<.001	[-.19, -.09]	26.6% (1.8)	[23.0%, 30.3%]
2nd-Floor Collaboration Hub	.20 (.10)	.001	[.08, .52]	.01 (.03)	.628	[-.04, .07]	34.5% (2.2)	[30.1%, 38.8%]

Note: Estimates are from a two-part model. Adjustment variables included weekday (1 of 7) and hourly observation time (94 per space; daily observations varied by hours of library operation).

Ratios (IRR), interpreted as the rate of change in the work count between each renovated space compared to the Fishbowl, calculated as a factor of $[(IRR-1) \times 100]$. For example, an IRR of 1.25 for a specific space means that the work count increased by 25% when compared to the Fishbowl. Model results indicated that, when compared to the Fishbowl, the renovated 1st-Floor Collaboration Hub's total and individual work counts increased by 94% (IRR = 1.94, 95% CI = 1.80-2.08, $p < .001$) and 150% (IRR = 2.51, 95% CI = 2.29-2.75, $p < .001$), respectively. Conversely, when compared to the Fishbowl, the Research Commons and 2nd-Floor Collaboration Hub total and individual work counts decreased by 12% - 66% ($p < .05$; see Table 2).

RQ 1.2: Group Work Location

Table 2 also demonstrates that, although the group work count rate of change was 20% higher in the 1st-Floor Collaboration Hub compared to the Fishbowl, the increase was not significant (IRR = 1.20, 95% CI = .96-1.48, $p = .103$). The rates of change in 2nd-Floor Collaboration Hub and Research Commons group work counts were 65% (IRR = .35, 95% CI = .28-.45, $p < .001$) and 74% (IRR = .26, 95% CI = .20-.33, $p < .001$) lower when compared to the Fishbowl, respectively. Since these estimates did not account for differences in the number of students working in each space

when counts were recorded, group work percentage data were also analyzed. Table 3 presents results from the adjusted two-part model that examined group work percentage. "First part" results indicated that the likelihood of group work percentage being positive and not zero was 7% and 20% lower in the Research Commons [AOR (adjusted odds ratio) = .07; 95% CI = .02-.18, $p < .001$] and 2nd-Floor Collaboration Hub (AOR = .20; 95% CI, .08-.52, $p < .001$), respectively, when compared to the Fishbowl. The estimated 48% lower likelihood of group work percentage being positive in the 1st-Floor Collaboration Hub compared to the Fishbowl was not significant (AOR = .48; 95% CI = .18-1.29, $p = .146$).

"Second part" results revealed that, for every one-unit increase in group work percentage in the Fishbowl, group work percentage decreased by 17% in the Research Commons ($\beta = -.17$; SE = .03, 95% CI = -.22-.11; $p < .001$) and 14% in the 1st-Floor Collaboration Hub ($\beta = -.14$, SE = .03; 95% CI = -.19-.09, $p < .001$). The estimated 1% increase in group work percentage in the 2nd-Floor Collaboration Hub when compared to the Fishbowl was not significant ($\beta = .01$, SE = .03, 95% CI = -.04-.07; $p = .628$).

Figure 3 and the "Average Adjusted Predictions" columns in Table 3 illustrate predicted group work percentage from the combined two-part model and 95% confidence intervals.

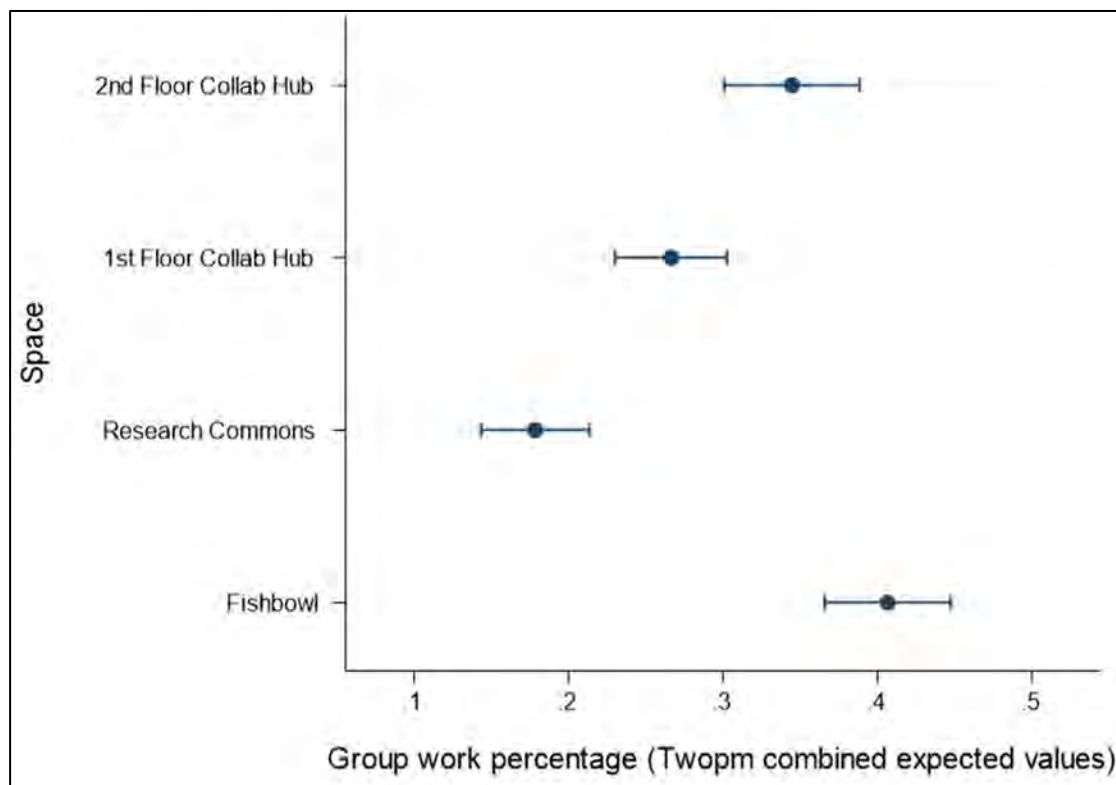


Figure 3. Adjusted Average Group Work Percentage by Space with 95% Confidence Intervals

Table 4. Student Group Work Location Preferences and Factors Influencing Those Preferences								
Group work location preference - library	Total Mentions	%	Group work location preference - campus	Total Mentions	%	Factors influencing location preferences	Total Mentions	%
Enclosed study rooms	28	32.2%	Student centers	30	34.5%	Noise level	63	72.4%
Fishbowl	26	30.0%	Dorm study areas	11	12.6%	Space availability	56	64.4%
1 st floor, renovated	9	10.3%	Other campus buildings	17 (1-3 in each of 12 buildings)	19.5%	Furniture type/availability	47	54.0%
2 nd floor, renovated	7	8.1%				Lighting quality	41	47.1%
1 st floor, unrenovated	6	6.9%				Location	41	47.1%
2 nd floor, unrenovated	6	6.9%				Operating hours	40	46.0%
Tables/whiteboards	6	6.9%				Resource availability	34	39.1%
Booths	4	4.6%				Food availability	34	39.1%
Library lobby	3	3.5%				Ambience	32	36.8%
Scholars lounge	1	1.2%				Other	5	5.7%

Table 5. Students' Suggested Changes to Library Study Spaces to Support Group Work						
Suggested change	Mentions	%		Suggested change	Mentions	%
Increase reservable space	15	17.2%		Medium noise levels	6	6.9%
More/larger tables	12	13.8%		ID card access after hours	6	6.9%
More resources (e.g., whiteboards, power outlets)	11	12.6%		Improve reservation system	6	6.9%
Designated talkative/quiet areas	9	10.3%		Food availability	5	5.7%
Lighting	7	8.0%		Less couches	3	3.4%
Quiet desired	7	8.0%		Cleanliness	2	2.3%
More work space	7	8.0%		Nap area	2	2.3%
More group work areas	7	8.0%		Scholars lounge signage	1	1.1%

Based on estimated group work percentages, the highest group work percentage occurred in the Fishbowl (41%), followed by the 1st-Floor Collaboration Hub (27%) and Research Commons (18%). The 2nd-Floor Collaboration Hub's 35% group work percentage was not significantly different from the Fishbowl.

Student Questionnaire Results

RQ 2.1: Students' preferred campus locations for group work (RQ 2.1)

Of the 87 questionnaires completed, 79 (91%) were submitted by undergraduate students and 8 (9%) by graduate students working in the library. More than half (52%) of respondents preferred to conduct group work in the library, 25% in both the library and elsewhere, and 20% preferred locations other than the library for group work. Table 4 displays preferred locations for group work in the library and on campus as well as factors influencing those preferences. Within the library, 32% of respondents preferred enclosed study rooms and 30% preferred the Fishbowl. Other top responses included the renovated (18%) and unrenovated (14%) first and second floor library areas, including spaces observed in this study. On campus, respondents preferred on-campus student centers (35%) and dormitory study areas (13%). Twelve other discipline-specific buildings were also listed (20% of overall responses).

Factors influencing respondents' location preferences included noise (72%), available space (64%), and furniture type and availability (54%). Lighting quality, location, and operating hours, available resources, food availability, and

ambience were also reported factors (37%-47%). Students were also prompted to explain why lighting, noise, location, resources, and other factors influenced their preferences. Thirty-eight of the 63 who listed noise level as an influential factor stated that having some sound rather than silence (e.g., soft conversational background noise; four desired silence) and designated talkative and quiet areas were preferred, such as in campus student centers.

Regarding lighting quality, a desire for bright light, specifically, influenced location preferences (21 of 41 mentions). The availability of space (2), enclosed study rooms (7), large tables (16), desks (5), booths (5), and chairs that spin (3) was commonly mentioned concerning space and furniture availability. Dorm (15) and work (5) proximity were location factors. Resource availability factors included whiteboard availability (12), display monitor availability for presentations (4), and power outlet availability (4). One student listed aesthetics related to ambience. These explanations overlapped with students' suggested changes to library spaces to support group work.

RQ 2.2 Student-suggested changes to library spaces to support group work

Table 5 summarizes students' suggestions to improve library group work space. More reservable space (15), large tables (12), and available resources such as whiteboards and power outlets (11) as well as designated talkative and quiet areas (9) received the greatest number of mentions. Of the students who addressed noise level, 9 asked for designation of talkative and quiet areas, 7 asked for quiet spaces, and 6

asked for “medium” noise levels. Additional suggestions related to improved lighting quality and control (7); increased workspace quantity (7), group work areas (7), and food availability (5); allowing students to access spaces after hours via their student ID cards (6); improved study space reservation system (6); and other suggestions relating to furnishings, cleanliness, and signage (8).

increased workspace quantity (7), group work areas (7), and Table 6 summarizes overall themes from all student questionnaire responses in aggregate. Top items related to noise (74%), more large tables and table space (32%), bright

light (32%) and more reservable space (25%). Top group work space location preferences included the campus student centers (35%), enclosed library study rooms (32%), and the Fishbowl space (30%).

Discussion

This study examined whether renovating three existing library spaces, originally designed for printed material storage and individual work, encouraged group work as intended. Observation findings suggested that post-renovation space use was fairly aligned with renovation

Table 6. Summary of Student Preferences for and Suggested Changes to Library Group Work Spaces

Topic	Description	Mentions	Topic	Description	Mentions
Noise	Desire background noise	44	Light	Desire bright light	28
	Desire quiet areas	11	Food	Increase availability	5
	Designate noise expectations	9			
Furniture	More large tables	28	Location preferences for group work	Enclosed library study rooms	28
	More desks	5		Library open space (Fishbowl)	26
	Add chairs that spin	3		Campus student centers (2)	30
	Fewer couches	3		Dorm study areas	11
Group work spaces	More reservable space	22	Location preference influences	Proximity to dorm	15
	More group work areas	7		Proximity to work	5
	Improve reservation system	6	Other	More workspace (overall)	9
	Add booths for group work	5		Extend ID card access hours	6
Tools and resources	Whiteboard	12		Add a nap area	2
	Display monitor/TV	4	Improve cleanliness	2	
	Power outlets	4	Add signage	1	

goals to support group work. After adjusting for day and time, statistical models revealed that the 1st- and 2nd-Floor Collaboration Hubs had higher group work percentages than the Research Commons space that was intended for mostly individual work. The 1st-Floor Collaboration Hub was used the most overall based on both individual and group work counts. The unrenovated Fishbowl, however, had the highest percentage of group work. Observation and questionnaire results indicated that the Fishbowl was the most used and preferred library space for group work, after the fully enclosed group rooms.

Findings were consistent with existing literature on influences of spatial openness, enclosure, and visibility on social behavior (Evans & McCoy, 1998; Fox & Doshi, 2013; Greenbie, 1981; Hua et al., 2010; Kim et al., 2021; Zimring, 1982). According to this literature, differences observed in individual and group work across the four observed spaces could be partially explained by design variations in openness, enclosure, and visibility. The unrenovated Fishbowl likely had the highest group work percentage because of its increased openness, decreased enclosure surrounding numerous, spread-out furniture arrangements, and increased visibility from outside and within the space. According to the workplace literature, these design characteristics likely invited groups and encouraged interaction (Hua et al., 2010; Kim et al., 2021). Once talkative groups were present, those seeking quiet places to work avoided the space while groups looking for areas to converse with background noise were drawn to the space. By comparison, the 1st-Floor Collaboration Hub's less open, less visible, and more enclosed spaces that included traditional rows of library tables spaced closer together than the Fishbowl may explain why a greater percentage of group work was observed in the Fishbowl. Moreover, much of the group work observed in the Collaboration Hubs occurred in the enclosed study rooms and not the areas with library tables. The presence of individual workers in those areas created a quiet atmosphere that discouraged group interaction as well as left less space for groups to sit.

Questionnaire responses that reported preferences and suggested improvements for library group work spaces with some level of noise (51%) and articulated noise level expectations (10%) were also consistent with literature documenting people's preferences for collaborating in spaces that encouraged and provided some background noise via conversation, music, or other sounds and signage indicating that talking is acceptable, regardless of whether the space was designed for group work (Bedwell & Banks, 2013; Foster & Gibbons, 2007; Lange et al., 2016). Students in this study likely preferred the Fishbowl's more open, less enclosed, and more visible space and the 1st-Floor Collaboration Hub's fully enclosed study rooms for group

work because of these environmental cues that signaled they could comfortably speak without disrupting others. Reservable, fully enclosed group rooms were also likely more popular for groups as students must coordinate schedules and identify a space for group meetings in advance.

Existing literature also indicated that library occupants often require clear articulation of noise levels to perceive library spaces as acceptable for conversation associated with group work (Given & Leckie, 2003; Ojennus & Watts, 2017). Group workspace preferences for campus student centers outside of the library and associated questionnaire responses demonstrated that students thought they could not speak in library areas they perceived as quiet spaces. Instead, they identified spaces for group work with background noise outside of the library, even if they wanted to be able to work in groups within the library. Library staff interventions, such as articulating acceptable noise levels in spaces, designating spaces for group work, and implementing reservation systems for group work space, may be necessary to increase group work especially in spaces where design features associated with quieter individual work are present. Developing and evaluating clear library policies regarding reserving study space and appropriate use of shared space (e.g., noise levels) is also likely necessary (Given & Leckie, 2003).

Strengths and Limitations

This research extended existing literature that examined influences of openness, enclosure, and visibility on social behavior in workplaces and other settings to academic libraries. These design characteristics, largely lacking in the academic library literature focused on interior, technological, and operational attributes, are promising areas for further research on group work spaces in academic library settings. The one-week multi-method research design also offered an approach that is transferable to evaluations of other library space renovations (Khoo et al., 2016). Combining quantitative data about the quantity, location, and timing of individual and group work with qualitative user responses to explain the observed use patterns is necessary for intervention (Given & Leckie, 2003). The mixed-methods approach can inform identification of interventions and where implementation is likely most effective, as well as future evidence-based decisions during library renovation and new construction.

Three study limitations must also be noted. First, generalizability was limited due to the single site design and self-selecting questionnaire participants. A more representative questionnaire sample is needed to document group work space preferences and suggested improvements, including from those who chose not to use

library spaces. Second, observations did not always distinguish between groups of students working individually and groups of students collaborating on a shared project. According to prior work, spatial needs and preferences may vary based on this distinction (Kim et al., 2021). For example, student groups may desire enclosed, private and reservable group spaces while students visiting the library in groups to work individually may desire more social spaces with background noise where they can clearly converse without disrupting others. Third, the study design did not enable authors to disentangle the effects of openness, enclosure, and visibility on group and individual work. Future research is required to fully understand how each of these design characteristics affects user behavior in library spaces for group and individual activity (Given & Leckie, 2003; Kim et al., 2021).

Conclusion

This cross-sectional, observational study explored whether the renovation of three spaces, originally intended for printed material storage and individual work, to encourage group work did so as intended. Observations revealed that, although one renovated space was used the most overall for both individual and group work, a fourth unrenovated space observed for comparison still hosted the greatest percentage of group work. Variations in spatial openness, enclosure, and visibility at least partially explained these observations. Questionnaire responses further noted additional attributes – many of which related to openness, enclosure, and visibility – that students perceived as necessary to support group work. Designated quiet and talkative areas, space and furniture variety and availability, lighting quality, operating hours, reservable space, and additional tables offered insights to inform future Hesburgh Library group work space research, design, and evaluation. Taken together, findings from this study highlighted the need for alignment of library space design, resources, and operational policies that support individual and group work.

Acknowledgments

The authors thank Lauren Jhin, former University of Notre Dame (UND) undergraduate student, for her work on this project; University of Michigan Research Assistant Professor HwaJung Choi for statistical consulting; and UND library staff and research assistants for their assistance with data collection and entry.

References

- Bailin, K. (2011). Changes in academic library space: A case study at the University of New South Wales. *Australian Academic & Research Libraries*, 42(4), 342-359.
- Beckers, R., van der Voordt, T., & Dewulf, G. (2015). A conceptual framework to identify spatial implications of new ways of learning in higher education. *Facilities*, 33(1/2), 2-19.
- Bedwell, L., & Banks, C. S. (2013). Seeing through the eyes of students: Participant observation in an academic library. *Partnership: The Canadian Journal of Library and Information Practice and Research*, 8(1).
- Belotti, F., Deb, P., Manning, W. G., & Norton, E. C. (2015). Twopm: Two-part models. *The Stata Journal*, 15(1), 3-20.
- Bennett, S. (2007). First questions for designing higher education learning spaces. *The Journal of Academic Librarianship*, 33(1), 14-26.
- Bennett, S. (2009). Libraries and learning: A history of paradigm change. *portal: Libraries and the Academy*, 9(2), 181-197.
- Bryant, J., Matthews, G., & Walton, G. (2009). Academic libraries and social and learning space: A case study of Loughborough University Library, UK. *Journal of librarianship and information science*, 41(1), 7-18.
- Burton, F., & Kattau, M. (2013). Out of sight but not lost to view: Macquarie University Library's stored print collection. *Australian Academic & Research Libraries*, 44(2), 102-113.
- Chacon Vega, R. J., Gale, S. P., Kim, Y., Hong, S., & Yang, E. (2020). Does an open-plan office actually work? A workplace gap analysis: importance and perceived support of key activities. *Journal of Corporate Real Estate*, 22(4), 261-277. 10.1108/JCRE-03-2020-0014
- Clements-Croome, D. (2015). Creative and productive workplaces: a review. *Intelligent Buildings International*, 7(4), 164-183.
- Congdon, C., Flynn, D., & Redman, M. (2014, October). Balancing “we” and “me”: The best collaborative spaces also support solitude. *Harvard Business Review*.

- <https://hbr.org/2014/10/balancing-we-and-me-the-best-collaborative-spaces-also-support-solitude>
- Cornell, P. (2002). The impact of changes in teaching and learning on furniture and the learning environment. *New directions for teaching and learning*, 2002(92), 33-42.
- Crook, C., & Mitchell, G. (2012). Ambience in social learning: Student engagement with new designs for learning spaces. *Cambridge Journal of Education*, 42(2), 121-139.
- Evans, G. W., & McCoy, J. M. (1998). When buildings don't work: The role of architecture in human health. *Journal of Environmental psychology*, 18(1), 85-94.
- Foster, N. F., & Gibbons, S. L. (2007). *Studying students: The undergraduate research project at the University of Rochester*. Assoc of Cllge & Rsrch Libr.
- Fox, R., & Doshi, A. (2013). Longitudinal assessment of "user-driven" library commons spaces. *Evidence Based Library and Information Practice*, 8(2), 85-95.
- Gisolfi, P. (2018). *Collaborative library design: from planning to impact*. ALA Editions, American Library Association.
- Given, L. M., & Leckie, G. J. (2003). "Sweeping" the library: Mapping the social activity space of the public library. *Library & Information Science Research*, 25(4), 365-385.
- Graetz, K. A., & Goliber, M. J. (2002). Designing collaborative learning places: Psychological foundations and new frontiers. *New directions for teaching and learning*, 2002(92), 13-22.
- Greenbie, B. B. (1981). *Spaces: dimension of the human landscape*. Yale University Press.
- Haapakangas, A., Hongisto, V., Eerola, M., & Kuusisto, T. (2017). Distraction distance and perceived disturbance by noise—An analysis of 21 open-plan offices. *The Journal of the Acoustical Society of America*, 141, 127–136.
- Harrop, D., & Turpin, B. (2013). A study exploring learners' informal learning space behaviors, attitudes, and preferences. *New Review of Academic Librarianship*, 19(1), 58-77.
- Head, A. (2016). Planning and designing academic library learning spaces: Expert perspectives of architects, librarians, and library consultants. *Librarians, and Library Consultants*.
- Hoendervanger, J. G., van Yperen, N. W., Mobach, M. P., & Albers, C. J. (2019). Perceived fit in activity-based work environments and its impact on satisfaction and performance. *Journal of Environmental psychology*, 65(101339).
- Holder, S., & Lange, J. (2014). Looking and listening: A mixed-methods study of space use and user satisfaction. *Evidence Based Library and Information Practice*, 9(3), 4-27.
- Hua, Y., Loftness, V., Kraut, R., & Powell, K. M. (2010). Workplace collaborative space layout typology and occupant perception of collaboration environment. *Environment and Planning B: Planning and Design*, 37(3), 429-448.
- Iyengar, S. S., & Lepper, M. R. (2000). When choice is demotivating: Can one desire too much of a good thing? *Journal of personality and social psychology*, 79(6), 995.
- Kang, S., Ou, D., & Mak, C. M. (2017). The impact of indoor environmental quality on work productivity in university open-plan research office. *Building and Environment*, 124, 78–89.
- Khoo, M. J., Rozaklis, L., Hall, C., & Kusunoki, D. (2016). "A really nice spot": Evaluating place, space, and technology in academic libraries. *College & Research Libraries*, 77(1), 51-70.
- Kim, Y., Hong, S., & Yang, E. (2021). Perceived Productivity in Open-Plan Design Library: Exploring Students' Behaviors and Perceptions. *Journal of Learning Spaces*, 10(3), 28-42.
- Lange, J., Miller-Nesbitt, A., & Severson, S. (2016). Reducing noise in the academic library: the effectiveness of installing noise meters. *Library Hi Tech*.
- Latimer, K. (2010). Redefining the library: current trends in library design. *Art libraries journal*, 35(1), 28-34.
- Lawrence, P., & Weber, L. (2012). Midnight-2.00 am: what goes on at the library? *New library world*.
- Ludwig, L. (2010). Health sciences libraries building survey, 1999–2009. *Journal of the Medical Library Association: JMLA*, 98(2), 105.
- McKay, D., & Buchanan, G. (2014). On the other side from you: how library design facilitates and hinders group work. Proceedings of the 26th Australian Computer-

- Human Interaction Conference on Designing Futures: the Future of Design,
- Montgomery, S. E. (2014). Library space assessment: User learning behaviors in the library. *The Journal of Academic Librarianship*, 40(1), 70-75.
- Montgomery, S. E., & Miller, J. (2013). The third place: The library as collaborative and community space in a time of fiscal restraint. In *Leveraging Library Resources in a World of Fiscal Restraint and Institutional Change* (pp. 102-112). Routledge.
- Ojennus, P., & Watts, K. A. (2017). User preferences and library space at Whitworth University Library. *Journal of librarianship and information science*, 49(3), 320-334.
- Ozburn, L., Kirk, J., & Eastman, T. (2020). Creating collaborative library spaces through partnerships with campus organizations. *Journal of Library Administration*, 60(6), 600-612.
- Revell, G. (2014). El tren fantasma: Arcs of sound and the acoustic spaces of landscape. *Transactions of the Institute of British Geographers*, 39(3), 333-344.
- Sinclair, B. (2007). Commons 2.0: Library spaces designed for collaborative learning. *Educause Quarterly*, 30(4), 4.
- Taylor, R. B. (1988). *Human territorial functioning: An empirical, evolutionary perspective on individual and small group territorial cognitions, behaviors, and consequences*. Cambridge University Press.
- Vaska, M., Chan, R., & Powelson, S. (2009). Results of a user survey to determine needs for a health sciences library renovation. *New Review of Academic Librarianship*, 15(2), 219-234.
- Waxman, L., Clemons, S., Banning, J., & McKelfresh, D. (2007). The library as place providing students with opportunities for socialization, relaxation, and restoration. *New library world*, 108(9/10), 424-434.
- Yoo-Lee, E., Lee, T. H., & Velez, L. (2013). Planning library spaces and services for Millennials: an evidence-based approach. *Library Management*, 34(6/7), 498-511.
- Zimring, C. (1982). The built environment as a source of psychological stress: impacts of buildings and cities on satisfaction and behavior. *Environmental stress*, 151-178.