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Smart Little Campus Food Pantries: Addressing food insecurity at Virginia Commonwealth University

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Abstract

Food insecurity among college students is an emerging public health issue, affecting a considerable proportion of the student population nationwide, approximately 35–45%. Research is discovering links between college student food insecurity and physical and mental health, as well as academic performance. Such high prevalence of student food insecurity highlights the urgency of addressing the

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Author Note

The authors declare no conflicts of interest.

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lack of consistent access to nutritious food. This research examines a pilot intervention at an urban public university that deployed miniature food pantries across campus from which anyone could take food anonymously. The research team systematically restocked these pantries with food on a weekly basis for nearly two school years. Sensors installed in the pantries collected instances when individuals "interacted" with the pantry's door. The sensor system documented thousands of interactions with the pantries each school year. As such, the intervention can be considered a success. However, the miniature pantry model was not without flaws: its decentralized nature created challenges for the research team, the sensor system was often unstable, and heavy reliance on undergraduate students proved a long-term problem. The research team believes that administrative and information technology improvements could further enhance the model's ability to mitigate campus food insecurity. This intervention could be an inspiration to other campuses and other institutions considering similar strategies.

Keywords
college student, higher education, food insecurity, intervention, food pantries, Internet of Things

Introduction

A national study found that approximately 35–45% of college students experience food insecurity or limited food access (Broton & Goldrick-Rab, 2017; Goldrick-Rob et al., 2017). College student food insecurity is emerging as a national public health concern due to the multilayered impact food security has on young adults (Bruening et al., 2016; Martinez et al., 2018; U.S. Government Accountability Office, 2018). Food insecurity significantly impacts the physical health, mental well-being, and academic achievement of college students. Scholars have linked food insecurity to a multitude of consequences for college students, including declining physical health (e.g., fatigue, poor sleep, disordered eating), mental health (e.g., increased stress levels, depressive symptoms, and anxiety), and academic achievement (e.g., impaired focus, lower grades, and reduced engagement with campus life) (Becerra & Becerra, 2020; El Zein et al., 2019; Haskett et al., 2020; Kim & Murphy, 2023; Payne-Sturges et al., 2018). Despite these troubling findings, the first congressional hearing on college student food insecurity did not occur until September 2021, but resulted in no substantive legislative action (Ending Hunger in America: Examining Hunger on College Campuses, 2021).

Food insecurity can be understood as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (Christaldi & Castellanos, 2017, p. 16), and has also been linked to the cultural appropriateness of food an individual might consume (Leroy et al., 2015). Food insecurity is often reported when insufficient financial resources occur as a result of an unexpected life event (e.g., going to college, changing employment, health, or marital status) and/or the absence of savings to buffer economic shocks (Bickel et al., 2000). Student food insecurity is an equity issue that affects many students, but students from diverse and/or low-income backgrounds generally experience this challenge at greater rates than other students (El Zein et al, 2019). The following types of undergraduate students at the University of California Davis were found to be at higher risk of food insecurity: transfer students, first-generation students, fourth-year students, and students of Latino(a)/Chicano(a)/Hispanic heritage (Tanner et al., 2023).

Given the growing evidence of the prevalence and negative consequences of food insecurity among college students, collaboration between institutions of higher education, policymakers, and community organizations is crucial. Implementing targeted programs such as food pantries, meal-sharing initiatives, and financial aid resources can play a vital role in supporting food-insecure students and ensuring the well-being and success of all college students, regardless of their economic circumstances. However, this may be easier said than done for several reasons. Several groups of scholars have noted the challenge of operating effective interventions on campuses, especially when student voices were absent from their management (Coleman-Jensen et al., 2019; Freudenberg et al., 2019; Goldrick-Rab et al., 2019). The Government Accountability Office noted that college

administrators are often unprepared to assist students with basic needs like food insecurity (U.S. GAO, 2018). Ellison et al. (2021) cautioned that existing food insecurity measurement tools are not validated for use with college students and urged standardized efforts to measure the problem. Davis et al. (2021) noted that more intervention-specific research is necessary to create evidence-based programming.

This study examines the effectiveness of one such intervention as part of the larger need to create evidence-based programming around college student food insecurity. Collected, quantifiable data is a necessary part of an evidence-driven approach to address food insecurity, first at a pilot project's local, university level, then as a collective effort in similar environments to better establish trends of need, usage, and impact. While it is argued that colleges must play a role in the food security of their students, just as they offer support for their mental well-being, this is a multifaceted issue that cannot be solely addressed at the university level. The collection of quantifiable, evidence-based research at the university and university-community level can build a case for changing policy and strategy at both the state and federal levels.

However, this sort of intervention-based research presupposes that higher education institutions should play a role in mitigating student food insecurity. Critiques of the emergency food system assert that the movement away from social welfare policies such as the Supplemental Nutrition Assistance Program (SNAP) and towards tax breaks for food producers and farmers to donate excess food to the emergency food system pipelines is ultimately a manifestation of neoliberalization, that helps the interests of capital at the expense of the human right to food (An et al., 2019; Fisher, 2017; Poppendieck, 1999; Tarasuk & Eakin, 2005). The research team is aware that college food pantries rely on this pipeline to secure food for students, and acknowledge this manner of research is technocratic in its efforts to optimize programming for colleges within the already fraught U.S. policy environment of food security in the post-pandemic environment. Any effort to ensure that college students have enough food to meet their learning goals requires both evidence-based programming on college campuses and, more importantly, national policy change towards a food system rooted in the right to food.

Background

Virginia Commonwealth University (VCU) is an urban, public university in downtown Richmond, Virginia. Across its liberal arts and medical campuses, VCU had roughly 30,000 undergraduate and graduate students enrolled in the 2022–2023 school year. Recent research found that roughly 35% of students, both undergraduate and graduate, at VCU were food insecure (Kim et al., 2022). This number appears to be consistent with peer universities across the U.S. (Broton & Goldrick-Rab, 2017).

In response, the research team launched a pilot program, the Little Ram Pantries (LRP), a decentralized, anonymous, sensor-enabled, miniature food pantry model that was systemically restocked by the research team. This title is an adaption of the Ram Pantry, the campus food pantry, named after the VCU mascot Rodney the Ram. This research tested the effectiveness of the pilot program, which drew inspiration from the "little free library" movement, semi-autonomous and spatially diverse neighborhood-scale book exchanges set up across much of the U.S. since the late 2000s (Sarmiento et al., 2018). These book exchanges use a publicly accessible box or similar device, often with a door, that contains books or similar media. People take or leave books in an anonymous manner. Adapting the little free library concept to emergency food assistance likely occurred sometime in the late 2010s (perhaps first in Arkansas in 2016, according to the Little Free Pantry website.[1] The COVID-19 pandemic may have spurred this adaptation as it allows contactless access to food (Carson, 2020). A member of the research team first observed a Little Free Pantry operating in a single-family neighborhood in Richmond in late 2020 and was inspired to bring the concept to VCU to help mitigate student food insecurity.

Data collection occurred over nearly two complete school years, 2021–2022 and 2022–2023.

[1] https://www.LittleFreePantry.org

During this initial pilot, the team developed a magnet-based sensor system operating on the campus Wi-Fi to gather anonymous, quantitative data whenever someone opened a pantry door. The team accepted these data, hereafter referred to as "interactions," as a proxy variable for pantry usage.

Limited examples of college operated Little Free Pantries exist. Scholarly documentation is lacking in this area, but some popular media articles and university websites provide limited information. Known examples include LaGrange College, Penn State Dickinson Law, University of Lynchburg, Surry Community College, North Dakota State, Lindenwood University, Columbia College, and Stockton University. These programs only have limited similarities to this pilot. Most appear to only operate one or two pantries and to obtain food only through direct donation by individuals. No operations appear to collect usage data.

Drake University appears to be an outlier, with two little pantries on campus and another eight in adjacent neighborhoods. All ten pantries are located outdoors. Supporters donate food directly into the pantries, and no centralized distribution system exists. Neighborhood groups own and manage the off-campus pantries. Staff from Drake's Office of Community Engaged Learning started the project in conjunction with an undergraduate leadership course. Office staff still nominally support the project by seeking groups to adopt individual pantries, both on and off campus, for short periods of time (e.g., a week or weeks). No standardized monitoring occurs, but Drake staff anecdotally report that the pantries are generally empty due to use, and that they were not aware of any major instances of food poisoning due to the outdoor nature of their model (A. Martin, personal communication, October 26, 2023; Drake University Office of Community Engaged Learning & Service, 2023).

The closest peer model to this pilot is the Campus Food Shed (CFS), a student-led project at the University of Wisconsin-Madison which deployed refrigerators at four campus locations. A student organization collected donated produce from local farmers and grocery stores, and gleaned produce from campus farms. Students distributed the produce into the refrigerators, from which users could engage with the pantry in an unrestricted manner, 24 hours a day, seven days a week. Major challenges CFS faced included concerns over food safety, transportation logistics, and data collection necessary to understand project effectiveness (DePorter et al., 2023).

Pilot Implementation

The LRP pilot program sought to both increase on-campus food accessibility and lower the potential stigma students might feel from accessing emergency food assistance programs, by deploying miniature food pantries in campus buildings (Kim et al., 2022). The LRP model allows individuals 24 hours a day, seven days a week access to emergency food assistance at geographically diffused points across the university and allows for nearly complete user anonymity. Access to the LRP was not means tested or otherwise controlled beyond existing inside official university buildings. The research team relied on many stakeholders spanning all parts of the university to implement the pilot. The team liaised with roughly 25 campus administrators, mostly during the development stage to secure necessary permissions, such as facilities staff, university counsel, branding/marketing, the Americans with Disabilities Act (ADA) coordinator, student affairs, financial administration, public relations, the university foundation, and university development.

The LRP program launched in October 2021, when the team deployed the first five pantries, with eight more pantries following in March 2022, for a total of 13 in operation across both campuses at the program's height. Data collection efforts ran over nearly two complete school years, from October 2021 to early May 2023, the conclusion of the school year. However, due to a host of issues, data collection from the five pantries located on the VCU medical campus proved too difficult for the team. The data presented herein is exclusively from the eight LRP located at the VCU liberal arts campus.

The research team employed magazine vending boxes to serve as LRP. The team made minor modifications to the magazine vending boxes to allow for data collection (i.e., mounting the magnetic sensors), as well as adding weight to increase

stability. The team consulted with the university's ADA coordinator to identify a low-cost, prefabricated device that was ADA compliant. Figure 1 shows a pantry in operation.

With one exception, all pilot LRP resided inside official university buildings. The team briefly deployed a pantry at a church community building adjacent to campus, but the team relocated it to a campus academic building after continued challenges connecting the sensor to church Wi-Fi. Most pantries resided in academic or communal buildings on campus such as the library and gym. Only one pantry resided in the lobby of a residence hall, but was later moved to an academic building due to Wi-Fi connectivity issues.

The research team ran a logistics operation to distribute food to the LRP on a weekly basis. A combination of service learning, volunteer, and paid students were primarily responsible for restocking pantries each week with pre-packed, shelf-stable food and hygiene products from Ram Pantry, the central campus food pantry. Ram Pantry acquires food through a combination of direct donation and purchasing from Feed More, the regional food bank for central Virginia. Distribution of food occurred weekly on Wednesdays, under the assumption that some food would be left in the pantries over the weekend. The team ruled out distribution on Fridays due to lack of student interest in supporting the project on Fridays. In addition, signage indicated that interested individuals could donate food and hygiene items directly to the LRP at any time.

Figure 1. A Little Ram Pantry in Operation

The team attempted to standardize weekly distributions, but inconsistencies occurred as different students engaged with the project. What food was available in the central Ram Pantry at the time also influenced what foods and how much could be distributed. The target minimum items per week include six complex carbohydrates; six proteins, including vegetarian options; at least three vegetables or fruits; two lipids or fats; three snack or sugary items; and two hygiene products. Once the team established the food pipeline from Feed More in October 2022, scarcity issues diminished but were still influenced by food availability at the regional food bank.

About 50 students were engaged at various points of the pilot operation. Initially, service learning students and volunteers supported early development, distribution, and observational data collection efforts, but this proved unreliable due to low student interest. The team then pivoted to paying students to manage weekly distribution and data collection, which proved more effective than using service learning teams, but some problems with reliability persisted. As the pilot period drew to a close, the team began to partner with administrative departments or groups to adopt the management of a specific pantry, generally spatially adjacent. Partnership examples include the staff of the campus library and gym and an academic department. Concurrently, student workers at the central Ram Pantry pre-packed bags and boxes weekly for distribution.

Method

This study examines two research questions involving the pilot project:

1. How are the Little Ram Pantries used?
2. Do the Little Ram Pantries help to mitigate student food insecurity?

The research team used two data collection methods to answer these questions: magnetic sensors built into the physical pantry boxes which generated timestamped data when someone opened the pantry door, and standardized visual observation data collected during weekly restocking of each of the LRP. These data collection protocols were approved by the Institutional Review Board of VCU.

Magnetic Door Sensor Data Collection

To collect general interaction data, the research team installed a cost-effective, lightweight, sensor system in the physical pantries to log the opening and closing of the doors. The system is autonomous, anonymous, and unobtrusive. It was designed to be "plug-and-play" for quick deployment, and to streamline normal updates and maintenance of the sensor systems.

The sensor system consists of a Raspberry Pi Model 3 A+ and a magnetic contact door switch from Adafruit. For longevity, the Raspberry Pi is powered using a 5-volt power supply connected to a wall outlet, but with regular charging the sensor system can operate on battery power, or with solar cells. The magnetic contact switch is a two-piece sensor; the magnet is placed on the door, while the switch is attached to the side of the pantry and connected by two wires to the Raspberry Pi. When the two pieces of the sensor are brought together, the switch 'closes' and the signal changes. When the door is open, the switch 'opens.' When the door status (switch status) changes from 'open' to 'closed,' or from 'closed' to 'open,' the Raspberry Pi logs the door status, a time stamp, and the date to a Google Sheet linked to each individual pantry. The code running on the Raspberry Pi manages monitoring the magnet sensor, logging data, and recovering from power outages and/or any Wi-Fi network outages.

Data collection using the sensor system occurred across two school years, October 2021 to May 2022 (i.e., the 2021–2022 school year) and August 2022 to May 2023 (i.e., the 2022–2023 school year). Sensors continued to operate during winter and summer breaks, but the research team was not actively refilling LRP or otherwise supporting the project during those periods. Sensor data first became available with the deployment of the initial five pantries in October 2021, and expanded to include three more in March 2022 for a total of eight pantries. The team deployed five LRP to the VCU medical campus, but instability of that campus Wi-Fi network, and geographic separation, led the team to reject data from them for this research.

Data generated by the magnetic door sensors were interpreted as "interactions" with the pantries, as the anonymous nature of the pilot prevented other inferences beyond someone opening the pantry door. Because of the indoor nature of this pilot, non-human actions or events tripping the sensor (e.g., wind or an animal) were not expected. The following five potential human actions could be inferred from an open/close "interaction" with a pantry measured by the sensor: (1) food was taken, (2) food was left, (3) some food was taken and other food left, (4) something unexpected or unmeasurable occurred, and (5) the user observed the contents of the pantry but did nothing. The team accepted these "interactions" as a proxy variable for usage of the pantry. The team developed a data visualization tool to interpret these data, and to allow our administrative partners and other interested parties at the university to understand usage patterns at the LRP. The tool was developed initially by an undergraduate co-author using MATLAB for local analysis of trends over time. This dashboard displayed annual, monthly, and weekly patterns for single locations and for the collection of deployed LRP. As the project expands, the team will rewrite the dashboard for incorporation into a live webpage, retaining the same base functionality and including interactive filtering.

Observational Data Collection

Students supporting the project distributed food weekly to each pantry location throughout both

examined school years. As part of weekly distribution to each location, students used a virtual observational data collection form on their smartphones to collect data about safety issues at the pantry, as well as pictures of the contents of the pantry boxes. Zeisel's (2006) work inspired the creation of the observational research form. Students were instructed to complete the form before refilling the pantry as part of the weekly restock. The 12-item form included questions about presence of unapproved or damaged food, vandalism or damage to the box, and if the sensor was plugged into the wall electrical outlet and unmolested. Students reported the form took less than five minutes to complete.

A combination of service learning, volunteer, and paid students, as well as occasionally members of the research team, completed these weekly forms. A total of 240 responses were collected over the two school years (n = 137 during the 2021–2022 school year, and n = 103 during the 2022–2023 school year). Instances of damage, vandalism, or the presence of inappropriate foods in the pantries were so rare that no analysis beyond basic descriptive statistical analysis was required. Pictorial data collected by the students through the form helped the research team understand limited instances of inappropriate use of the LRP.

Results

The presentation of results follows the research questions.

1. How are the Little Ram Pantries used?

Data from the sensor system suggests that many people engaged with the LRP. Due to their decentralized, anonymous nature, and the limitations of the sensor system, it is impossible to know if only students interacted with the LRP. Potentially some combination of faculty, staff, visitors, and janitorial workers also may have interacted with the pantries. Furthermore, the nature of the sensor network made it impossible to identify unique users as well as the frequency of a unique user possibly interacting with an individual pantry or multiple pantries. The inability to identify unique users was at least partially intentional by the research team to protect potential users from having to self-identify as requiring food assistance, but technological costs associated with identifying unique users influenced this decision.

Across both school years a total of 7,957 interactions were recorded; 2,017 during school year 2021–2022 and 4,633 during school year 2022–2023, with 1,307 interactions recorded outside the normal school year when the research team was not actively restocking the LRP. Sensor data showed significant bias towards the gym and main library locations. The remaining locations showed roughly comparable rates of interaction. Table 1 shows total interactions per location, as well as per school year. The names of some locations were generalized to increase readability. The research team moved one pantry that was located in a low visibility space in the lobby of a university-owned student dormitory to the Life Sciences building early in the Spring 2023 semester due to the combination of low interactions, Wi-Fi instability, and geographic remoteness for the research team.

Users most commonly interacted with the pantries in the afternoon, with 1:00 p.m. the most common hour. However, users interacted at all hours of the day. Across the entire pilot, 809 interactions occurred in the middle of the night (i.e., from midnight to 7:59 a.m.). Figure 2 shows interactions by time of day across all locations. Some pantries located in academic buildings, such as the School of Social Work or the General Education building, were inaccessible during non-academic hours, thus preventing people from interacting with those LRP at those times.

Unfortunately, the pilot was not without some instances of vandalism. Unknown individuals unplugging the sensor power cord was a fairly common occurrence, with roughly 14% of weekly observations noting this. This was especially common at the pantry in the lobby of the School of Social Work, where the team inferred that students would unplug the sensor to plug in their laptop when studying in the chairs located a few feet from the pantry. In at least six instances, unknown individuals either stole the sensor power cords or the USB wall adaptors. No spatial pattern to this vandalism was observed. This led the team in January 2022 to work with university facilities to upgrade the electrical outlets used by the project to contain USB ports, thereby removing the need for a USB

Table 1. Interactions by Pantry Location

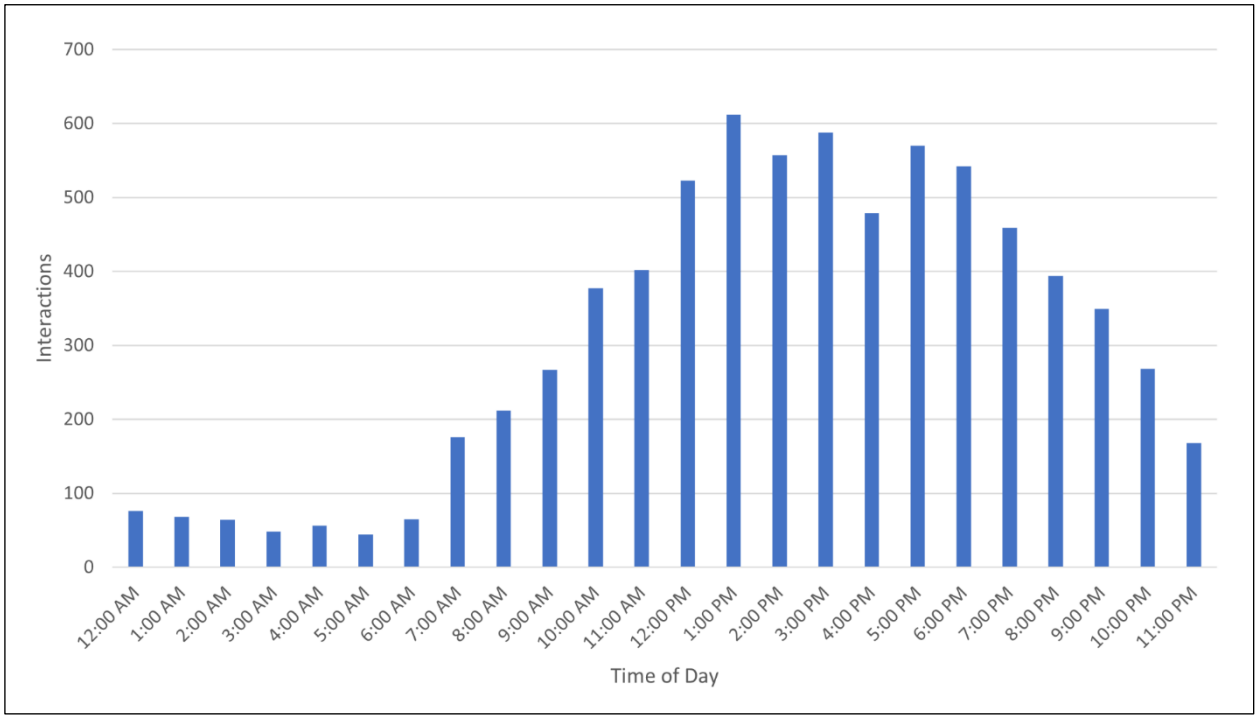
Pantry Location	Total Interactions[a]	2021–2022 School Year	2022–2023 School Year
Gym	2,280	485	1,393
Main Library	2,428	632	1,444
Student Commons[b]	729	397	233
School of Social Work	977	285	433
Student Dorm/Life Sciences Building	400	131	244
Business School	410	26	384
Engineering School	627	27	462
General Education Building	106	34	40
Totals	**7,957**	**2,017**	**4,633**

[a] Includes both school years as well as Winter Break 2021–2022, Summer Break 2022, and Winter Break 2022–2023, during which the research team was not actively filling pantries, but some sensors kept recording. People not associated with the pilot could donate food into the pantries during these periods.
[b] Located outside the main campus pantry, effectively giving 24/7 access to the main pantry. However, regular Wi-Fi connectivity challenges plagued this location. Given its location, true usage was likely dramatically higher.

wall adaptor and hopefully removing competition for use of traditional electrical outlets. Despite this change, unknown individuals continued to unplug sensors for unknown reasons.

Only limited forms of misuse occurred beyond the sensor related vandalism. In five instances, students discovered either the movement or theft of signage or parts of the pantry. In four other instances, students discovered flyers of a commercial or political nature inside or on top of the pantries. In another instance, on the transparent plastic door of the pantry an individual had drawn abstract

Figure 2. Interactions by Time of Day Across All Locations



art, which was able to be removed with a wet cloth. The bay of one pantry was covered with a dried brown liquid of indeterminate source, which was cleaned up.

Students observed only limited instances of food being donated into the LRP inappropriately, and in no instances were those inappropriately foods of an imminently dangerous nature (e.g., no dairy products donated into an unrefrigerated pantry). Examples of inappropriately donated foods included a sack of potatoes, roughly a pound of rice in a tied plastic grocery bag, a similarly tied bag of dried pasta, and a single fresh orange. Students were instructed to place all of these items in the garbage. Students also threw out some expired products that were well beyond their listed "best by" dates. Data collection did not specifically track this, but anecdotally students reported that box macaroni and cheese and dried noodles were the most commonly well-expired products moved to garbage.

Finally, the research team was not aware of any instances of injury or harm to any individual during the pilot period. A very small potential exists that a user could have become ill from spoiled food, either unintentionally placed in one of the pantries or inappropriately donated foods (e.g., dairy products), but that illness was either not reported or could not be tied directly to food from the pilot.

2. Do the Little Ram Pantries help to mitigate student food insecurity?

Data from the sensor system and the observational data collected suggests that the pilot helped mitigate student food insecurity. However, available data can only suggest, as more expansive and definitive data collection (e.g., pre- and post-surveys) would be required for greater certainty. Such data collection would be ethically and logistically difficult.

At minimum, sensor system data found 6,650 total interactions over the two school years when the pilot was in formal operation, as well as 1,307 during summer and winter breaks when the pilot was not formally in operation. The school year-to-school year usage increased by 129.6% from 2021–2022 to 2022–2023, likely due to both the deployment of additional pantries in March 2022 and continued growing awareness of the pilot across the campus community. With current data collection tools, it is not possible to know in what percentage of interactions individuals took food, rather than other options. Further, due to current data collection tools, it is not possible to know how many unique users LPR assisted.

Data from the sensor system, when controlled for by day-of-the-week when the interaction occurred, revealed a noteworthy finding when considering that the research team consistently restocked each pantry on Wednesday. Across all locations, the highest number of interactions occurred on Wednesday, followed by Thursday, and onward till Sunday, the day with the fewest number of interactions. The Wednesday to Sunday decline was a 63.7% drop in total interactions, averaging a 15.9% decrease in interactions per day from Wednesday. On Monday, usage increased 120.4% from Sunday, then declined slightly on Tuesday. On average, each day after Wednesday experienced a 35.2% decline in interactions. Figure 3 shows interactions by day of the week for all locations. There are a total of 8,004 interactions included in this figure; approximately 0.6% variation from Figure 3 exists due to an estimation difference in valid interactions from students using the pantries versus the restocking or sensor testing interactions. These events could be estimated on a weekly basis, and largely occurred on Wednesdays, but to preserve valid interactions where the time of the restock or testing interactions were not precisely known, the data was left in the logs.

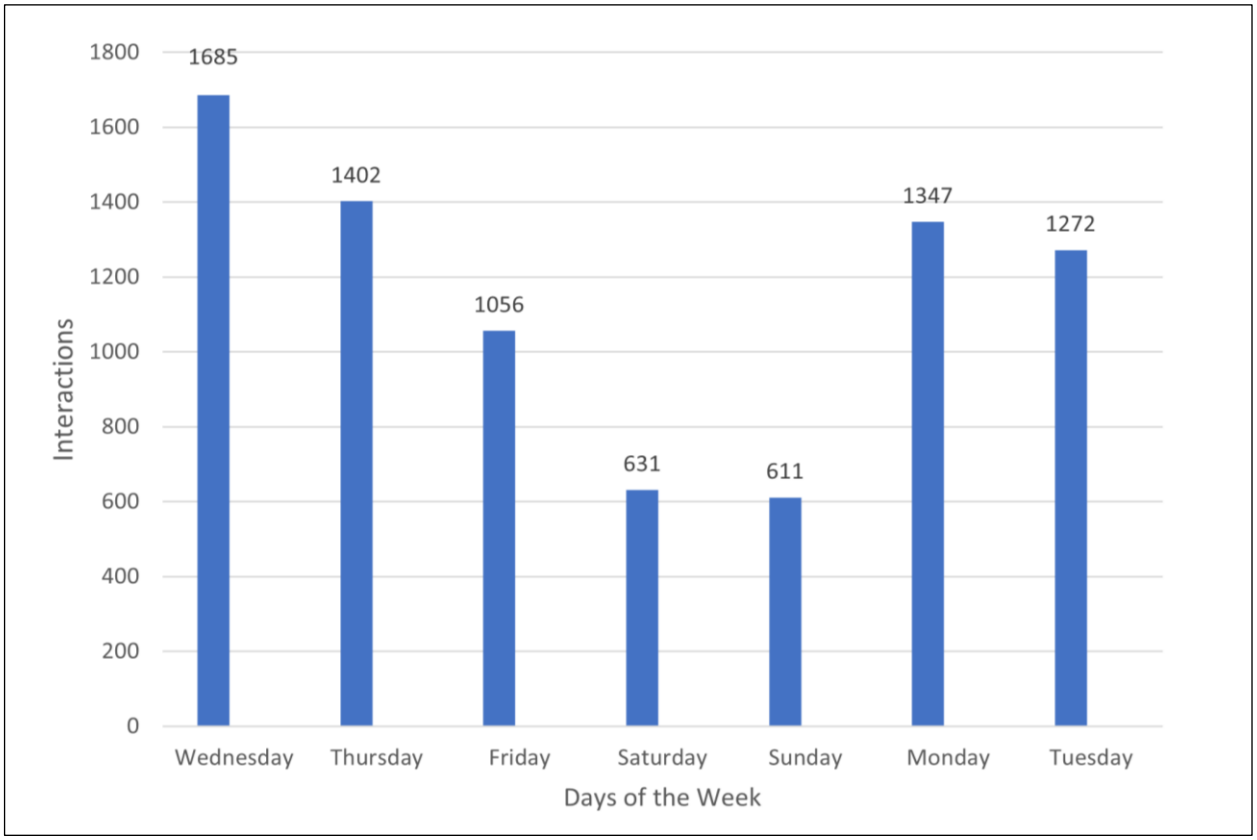
Discussion

Analysis of results suggests three major themes: functionality of the model, effectiveness of the pilot in mitigating food insecurity, and limitations of this research.

Functionality of Pilot as a Model

Analysis of the pilot program demonstrated that the intended goal of a decentralized, anonymous, Wi-Fi based sensor-enabled network of miniature food pantries with a structured restocking system functioned as intended. Data suggests that many people used LRP to obtain food. No known injuries or illnesses were reported to the research team.

Figure 3. Total Interactions by Day of the Week



No major instances of vandalism or other malfeasance related to the pilot were documented. Furthermore, development of the system was fairly cost effective. In total, the research team spent slightly less than $20,000 to implement the model over an approximate 24-months period. Costs include equipment and student labor costs, but did not include any salary support for faculty or staff on the research team or the cost of the food disbursed through the pilot. Using student labor, as service learners, volunteers, or employees, to physically disperse the food weekly and assist with logistics management proved challenging, but not insurmountable. Integrating the model into more established administrative elements of a university would significantly mitigate that problem. These results suggest that the pilot could serve as a model to other universities seeking to create similar programs. The general approach taken with the initial deployment and then the expansion across both campuses over the multiyear period has been thus far successful as a modular, scalable implementation.

Programmatic Effectiveness at Mitigating Food Insecurity

This research suggests that the overall model is likely effective in mitigating food insecurity on a college campus. The exact extent of that impact is unknowable, due to many methodological factors of practicality and limitations of data collection on food insecure college students, the ethics of collecting such data on that population, and the likely expenses required for such a project. Thus, the overall model might be understood to be as effective as reasonably possible to measure.

The research team had considered some measures to increase the potential of finding demonstrable impact, but rejected them on either ethical or practical grounds. For example, the team considered developing and installing a lock on the pantries that required a specifically coded ID card

to open, such as from a food insecure student. This system might allow for student users to be contacted for pre-and post-testing about the effectiveness of the pilot. However, the team rejected this idea both due to the cost as well as the ethics of creating a means-testing requirement (e.g., opting to identify oneself as food insecure to a campus official, creating administrative barriers to receiving aid).

At the same time, any discussion of the effectiveness of an intervention of this nature must also ask if other interventions or policy changes upstream might be more effective in mitigating the problem (Nazmi et al., 2019). For example, an intervention focused on the systemic donation of meal swipes from the campus meal plan to food insecure students might be more effective for interested faculty and staff to pursue. Expanding the eligibility of more college students to receive federal food assistance programs like the Supplemental Nutrition Assistance Program (SNAP) might be of even greater effectiveness.

Limitations

This research had a number of limitations. Primarily, due to the anonymous nature of the sensor network and the model design, recorded interactions cannot be specifically tied to usage by students. Anyone walking by a pantry could interact with the pantry by opening the door, thus generating a recorded interaction. The research team assumed that most interactions were by students but have no way of confirming this. The research team rejected suggestions about seeking to determine if students were interacting with pantries, due both to ethical (i.e., means testing and the Hawthorne effect) and practical concerns (i.e., expense and technical challenges of collecting such identifying data).

Furthermore, irregularities in readings from the sensor network were common, and individual sensors might not report for a number of reasons. Given the nature of the sensor network and the geographically dispersed nature of the pilot, days might pass before the research team could notice irregularities. Additionally, irregularities went undetected due to inability to remotely determine sensor functionality. Examples include Wi-Fi connectivity issues, power issues such as an outage for the entire building, malfunctions of sensor hardware, bugs in the sensor software code, and theft of power cords or wall adaptors.

Therefore, the sensor data reported should be understood as raw counts generated when the sensors were functional and someone opened the pantry door, rather than truly representative proxies for pantry usage. That should not undermine the value of the raw counts in understanding how many times people interacted with the pantries. If anything, consistency with the sensor data suggests that the number of interactions reported here are conservative estimates of true usage. Greater stability within the sensor network, and ability to remotely detect when a sensor was not functional, would allow for greater internal validity of data.

Additionally, the combination of undergraduate service learning, volunteer, and paid worker students over the two pilot school years also led to lack of consistency within the weekly restocking of food, during which the weekly observational data form was collected. In total, over 50 undergraduates assisted with this research in some capacity. Often students would not complete the research tasks as described by the research team during their orientation. Examples of non-compliance included completing the restock on a different day than instructed (Wednesday), not completing the restock, not completing the observational data collection form, or not completing elements of the observational data collection form. Sometimes the research team could catch these errors, but the highly dispersed nature of the pilot made it inconvenient for a member of the research team to then complete the required task. The labor-intensive nature of the model is a major limitation both in replicating research and implementing a similar model.

Lessons Learned, Expansion, Implications for Colleges, and Future Research

Practical Lessons Learned

The research team learned three major lessons during this pilot research. First, the decentralized nature of the pilot model was itself challenging, and relying on undergraduates to assist with logistics and management often proved unreliable. This led the team to consider a different management

model. In addition, clearer preliminary planning would likely have reduced information technology challenges; these are explored briefly below. The team encountered challenges noted by Hagedorn-Hatfield et al. (2023) that are common to the successful implementation and sustainment of food insecurity initiatives on college campuses: difficulty securing project funding, ensuring student awareness of the project, and overcoming perceptions of stigma. The research team intends to write about these challenges in other papers.

While the decentralized nature of the pilot intentionally created increased accessibility for users, it proved challenging for the research team. The VCU liberal arts campus is roughly 0.5-mile square in a dense urban environment. Campus buildings are interspersed around public streets. In some cases, the distance between either of the buildings where the research team had their offices or the main campus food pantry and a satellite pantry required a 10–15-minute walk each way. Canvassing each pantry across campus in a single outing might require more than an hour walk. For individual instances these distances were often not an issue, but sustained travel times over the course of the pilot's nearly two complete school years proved burdensome.

These challenges became even more pronounced when the research team deployed five LRP to the VCU medical campus in March 2022. Less than two miles of Euclidean distance separates the campuses, but Richmond's central downtown lies directly between the campuses. As no one from the research team members worked at the medical campus, managing these LRP quickly became untenable for inclusion in this research. Whenever possible, however, the team sought to supply those LRP with food and safety checks.

Second, this research relied heavily on a combination of undergraduate student service learners, volunteers, and work-study workers to manage the logistics of packing and delivering food to each pantry, each week. Effectively, the research team was running a micro-scale logistics operation for nearly two complete school years. While most students involved with the project were enthusiastic, and at times helped co-create aspects of the project, the lack of professional experience and the transient nature of student involvement significantly added to the complexity of the project's implementation.

There were several distinct examples of difficulties experienced during the pilot, which may be informative for others seeking to replicate the model on their campus. Student turnover, either due to graduation or completion of a class, required regular recruitment and training. Students often did not prioritize completing project tasks, even when employment or grading required it. This was especially true for volunteers. This lack of follow-through often resulted in food not being delivered, observational data not being collected, or sensors remaining unplugged. In some limited cases, students struggled to physically move the required food from the main pantry to the satellite locations. This was especially true for geographically removed locations that might require more than a 15-minute walk to reach, without considering carrying additional weight. The research team bought carts to assist, but these carts proved cumbersome to navigate through busy central city streets. Although mechanisms to alert the research team of the successful completion of certain weekly tasks, such as submission of the observational data form, were possible through Google Forms, initially the team did not use them, however, trying to minimize their daily volume of emails.

Collectively, both of these challenges led the team to realize that relying upon various forms of student labor was simply too unreliable for the model, especially a highly geographically dispersed model, to be sustainable. Towards the end of the pilot study, the team began to solicit partnerships with full-time administrative staff in buildings where the pantries were located to find individuals or groups willing to "adopt" the pantries. This would require willingness to store roughly one month of food for the pantry, and to restock the pantry from that supply and complete the observational safety form each week.

Challenges for the technology implementation were largely front-loaded for this project. The microcomputer, the Raspberry Pi, that collected data and logged it to Google Drive for sharing was chosen because of its small size, low cost, Wi-Fi connectivity, and sensor compatibility options.

However, at the time the project was started, a non-standard Wi-Fi connection work-around was needed in the software in order to connect to the university's private network. This created difficulty during setup and initial testing, but a subsequent software update from the manufacturer largely removed this complication. The team coordinated with the university IT department for Wi-Fi login credentials not tied to an individual account, and a non-university gmail account was created to allow access to Google Developer Tools. The most noteworthy challenges in developing the sensor system were managing network connectivity (e.g., deployment in Wi-Fi dead zones, areas with poor connectivity over time) and sustaining power to the individual sensors (e.g., theft of power cords and adaptors, building power outages) The team largely fixed them by moving some LRP to better locations and improving the stability of sensor code. LRP at locations with sustained Wi-Fi connectivity issues could be addressed by extending wireless coverage in coordination with IT and Network Services.

Expansion

As of this writing in early 2024, the research was moving towards expanding and refining aspects of the project to support greater sustainability at the home campus as well as expanding the model to other universities, and potentially non-collegiate organizations, such as K-12 schools, elder care facilities, and mutual aid organizations that operate outdoor LRP or community fridges.

Improvements to the sensor system are ongoing, with focus on expanding sensor type options and visibility of collected data. The current sensor systems use a single magnet per pantry to monitor door activity, but the Raspberry Pi boards are capable of interfacing with other sensors such as motion detectors, scales, temperature and humidity sensors for climate monitoring, and even small cameras. Strong emphasis is on unobtrusive sensors and data collection methods, as not to hinder usage. This flexibility allows for some customization for data collection needs without further complicating the system. Data from the sensors are currently logged in Google Sheets so that they can be viewed in real time. While this supports internal validation and monitoring, a public webpage with an interactive dashboard would provide location and basic usage statistics to users of the LRP, and other interested parties that might be inspired to set up their own satellite pantry system.

These improvements are paramount when considering how a university might source the food needed for this food pantry model. Any economically sustainable management model will likely include a partnership with a university's regional food bank, that requires the university to pay the food bank for shared maintenance costs for the storage, handling, and distribution of donated foods, but in turn the university can receive food donated through the national emergency food assistance system organized by Feeding America. These fees for partnering with a food bank will be minor in comparison to buying the same food at retail prices.

The U.S. Internal Revenue Code, Section §170e3, shapes the nature of food donations nationally, requiring food donations to be tracked from the farmer or manufacturer to the eventual individual pantry distributing the food. Regional food banks maintain these data to ensure compliance and can require individual pantries to report either the number of clients served or weight of food dispersed to corroborate intended people receiving the donated foods. Without a sensor system, the decentralized, anonymous nature of the pilot model would prevent effectively tracking the number of users, likely preventing a regional food bank from knowingly partnering with a university food pantry seeking to create such a model.

Additionally, the technological aspects of the system were designed to be scalable. Data was stored in a Google Drive, and every sensor system in a pantry was responsible for its own Google Sheet. When a new Raspberry Pi system is deployed, it creates the Sheet it will write to for its lifetime. By utilizing a one-to-one ratio with devices and files, the limit that Google sets to automated or scripted writing to documents is respected. This system is simple enough to recreate at other universities, and robust enough to support dozens of devices writing to the same Google Drive. As other sensors (i.e., scales, temperature sensors, cameras) are added to the system, it is

important to consider switching to a database or cloud storage such as Amazon Web Services (AWS) with more versatility in storage. Searchability and access time will be foregrounded when the live, web-based dashboard for displaying location, usage, and basic statistics is deployed.

Due to the physical nature of the pantry boxes, undergraduate students supporting this research consistently reported difficulty using the vertically mounted door on the pantries, which required the students to brace the door to keep it from slamming down while they refilled the pantry. Pantry users likely experienced the same conditions. Considering that the pantry boxes for the pilot were originally intended as outdoor magazine vending boxes, the research team sought to design and fabricate a device intentionally created to be a miniature campus food pantry. The team sponsored an undergraduate mechanical engineering Senior Design Capstone team during the 2022–2023 school year to design such a device. As part of the redesign, students tested an inward-facing camera system that would take a photograph of the pantry contents each time the door was closed. This could both inform pantry operations as well as provide avenues for additional research. The prototype is being tested during the Fall 2023 semester.

Implications for Colleges

As of late December 2023 the research team had advised senior administrative leaders at VCU about the research findings, along with recommendations for improving and sustaining the pilot. As of this writing, discussion with senior leaders was ongoing. The successes noted herein beg the question of how similar programs could fit into strategies of other institutions in reducing student food insecurity. While this research suggests the pilot model is effective and that administrative burdens for operating such a program likely are sustainable for many colleges, this model will not work at all colleges. Campuses that are geographically dispersed, highly urbanized, or that lack a centralized food pantry may struggle to implement a program such as this.

Furthermore, research of this nature into the effectiveness of interventions is important, but readers should not lose sight that any intervention at this scale is simply a bandage on a much larger societal problem of food insecurity. Colleges must play a role in improving food security for their students; this is crucial both ethically as well as from a student success perspective. However, food insecurity is a "wicked problem" that requires the intervention of federal policy to truly affect lasting change (Rittel & Webber, 1973). When considering how to best reduce student food insecurity, faculty and administrators should also bring their concerns to political leadership. The research team intends to explore this topic more in a future publication.

Future Research

Several avenues for future research presented themselves as part of this pilot project. First, this pilot research experienced several data collection limitations that future investigations into this model should seek to avoid. Specifically, greater stability within the sensor systems as well as greater consistency within weekly monitoring of LRP would improve internal validity. Replication of aspects of this research, especially at colleges and universities of differing characteristics, would be helpful in developing a picture of the true potential of this model to mitigate food insecurity on campuses.

Second, the research team considered the existence of "silent" interactions with the boxes: someone looking inside the box, which was possible as the door was transparent, seeing the contents, but for whatever reason deciding not to open the door. At face value, the person might not desire any of the pantry food, leading them to proceed with their day. However, that person's perception of what food was in the box, relative to their needs and their perceived need to not take more than they need, might also influence if they take food or not.

The following hypothetical illustrates this point. A food insecure student who does not necessarily perceive themselves as truly in need of food assistance approaches a pantry. Depending on how much food they see in the box, they may or may not take food. Their hesitance could be linked to the perception, regardless of accuracy, that another individual might have a greater need for food. This hesitance could be rooted in guilt,

shame, or politeness. Awareness of an impending restock of the pantry adds an additional layer to the decision making. Does the student take less before the scheduled restock than they would after the restock? Cultural appropriateness and dietary needs/preferences regarding the food in the pantry might also affect decision making. Availability of individual serving sizes, as opposed to larger containers with multiple servings, could be another factor. The perception of pantry "fullness" might also incentivize people experiencing less acute insecurity, as well as people not insecure but simply looking for free food, to take something. These silent interactions, and their implications, are likely of interest to a number of research approaches. Insight gained from such research could inform communication to the campus community about the pantry model to help users better understand how they fit into the system and help destigmatize the use of such a decentralized, anonymous system.

Finally, the inclusion of inward facing cameras as part of the sensor system in the redesign of the physical pantries would allow researchers to examine usage patterns to better understand what foods users took and when. User anonymity can be preserved by delaying image collection until after the doors have been shut, and it would add reliable observation points for vandalism and pantry conditions. Furthermore, the cameras would allow researchers to run quasi-experimental interventions to examine human behaviors. For example, student workers supporting the project reported that over the span of a few weeks an individual not associated with the research team had donated several boxes of sealed feminine hygiene products into the pantry in the business school. Each sealed box contained multiple "uses" or "servings." The students anecdotally reported that for some weeks, pantry users took individual "servings" from one of the opened boxes but did not take the sealed boxes with multiple servings. Eventually the students lost track of this behavior, but such a situation could be replicated if cameras were installed to test how long it would take before someone took a sealed box. Potentially, such a finding would have implications to counter the pessimistic narrative that suggests that "needy" or "desperate" people will take whatever they can, whenever they can. 

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