# Development and Impact of a Data Collection System for Academic Makerspaces

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### INTRODUCTION

The primary motives behind implementing the 'Shared User Management System' (SUMS, https://sums.gatech.edu/) in the Invention Studio at Georgia Tech were to gather both user and usage statistics data, allow users to enter the tool queue, and help enforce the safety policy. Usage data helps quantify the potential impact of the space and attract more donors and sponsors. Roberts and Buckley [1] have also shown the impact of their university's makerspace by conducting a survey and showing how it affected different groups on campus. Usage data also helps efficiently manage the tools and resources as well as planning and scheduling maintenance. During peak times, the Invention Studio requires greater supervision and automated queuing systems. The School's safety policy requires all users be aware of basic safety procedures. SUMS helps disseminate this information with little hassle on the user and the administration. A system which gathers tool usage and user statistics while keeping intrusion and human effort to a minimum are ideal for a makerspace environment and improves safety, work flow, and maintenance.

### METHODS OF DATA COLLECTION

Cooke and Charnas [2] have discussed several data collection methods that can create useful data for the makerspace, these include ID card readers, photo ID scanners, sign in apps, registrar or university data, and user surveys. Each of these methods has a different level of interaction with the user and different amounts of information. Another data collection method was used to measure the impact is Clear-Counter Active Automatic People Counters (APCs). The benefit of this method is that is has the least intervention and measures the number of users entering the space [3].

In the Higher Education Makerspaces Initiatives (HEMI), there are seven other universities other than Georgia Tech. A quick study was conducted to gain a better understanding of how various makerspaces collect data and use this data to improve their space and measure their impact [4]. Table 1 shows the summary of the different attributes of the data collection method utilized by the different makerspaces. Asterisk indicates the presence of the capability or attribute for the corresponding data collection method.

A legacy system used in the Invention Studio (designed and built by a volunteer student) served only as a simple queue for select equipment and did not generate usage data or keep track of training records. However, within the last year, the Invention Studio at Georgia Tech modified SUMS platform to use it as a replacement for the old system as well as meet the newer requirements of a data collection/management system. SUMS was being used used to enforce strict safety and training protocols in Georgia Tech's Institute for Electronics and Nanotechnology labs and a platform to generate invoice for users who utilize research equipment. The Invention Studio does not charge its users, as it is free for all of the campus community, but needed to gather usage statistics while requiring minimal effort from the user to keep the space as streamlined as usual. This paper presents the requirements determined for the data collection system for the Invention Studio and the resulting modified SUMS platform that was developed because of close collaboration between the authors worked closely with the developers of the SUMS platform.

*Table 1.a Review of data metrics collected at HEMI makerspaces*

| University | Yale | Case Western | Georgia Tech | UC Berkeley |
|---|---|---|---|---|
| Makerspace Name | CEID | Sears think[box] | Invention Studio | Jacobs Institute for Design Innovation |
| **User Data** | | | | |
| User name and contact info | * | * | * | * |
| Affiliation (school, major, etc…) | * | * | * | * |
| Training Record | * | * | * | * |
| **Equipment Data** | | | | |
| Operation Status | | * | * | * |
| Usage | | * | * | |
| Queueing System | | * | * | * |
| Maintenance | | * | * | |
| **Data Collection Method** | | | | |
| Paper writing | | | | |
| Typing to login | * | * | | |
| Cell phone login | | | | |
| ID login | * | * | * | * |

*Table 1.b Review of various data metrics used at different universities.*

| University | Carnegie Mellon | Stanford University | Olin | MIT |
|---|---|---|---|---|
| Makerspace Name | IDeATe | Create: Space | The Shop | MIT Maker System |
| **User Data** | | | | |
| User name and contact info | * | * | * | * |
| Affiliation (school, major, etc…) | * | * | | * |
| Training Record | | * | * | * |
| **Equipment Data** | | | | |
| Operation Status | | * | | * |
| Usage | * | * | * | |
| Queueing System | | | | |
| Maintenance | | | | |
| **Data Collection Method** | | | | |
| Paper writing | | | * | |
| Typing to login | | * (online) | * | * |
| Cell phone login | | | | |
| ID login | * | | * | * |

*Makerspace & User Requirements*

From table 1 it was determined that makerspaces generally collect three main types of user data, namely user's contact information, school affiliation, and training records. Four levels of equipment data collected includes information of equipment usage based on time, operation status, maintenance information and queue management. Makerspaces generally use an electronic data collection system. Primary form of these are manual entry on a keyboard or scanning of an identification badge.

An essential administrative requirement for the Invention Studio was to allow users to electronically accept a safety agreement. This is a one-time agreement that all users of the space have to agree prior to utilizing any tools in the Studio. A data collection system for the Invention Studio had to incorporate needs from both a user's and a PI's (Prototyping Instructor, student volunteer staff) perspective. It was necessary that the users should be able to view and accept the agreement upon first login, without having to search for specific links. Similarly, it was also required that the list of users be easily accessible on the backend for record keeping and data analysis. For more operational functions, it was necessary that users could simply scan their ID badge to access the list of available tools and log into them without having to type anything – all from a touchscreen kiosk. From the studio's perspective, it was necessary to quickly add and remove staff (who possess higher administrative permissions), since the Studio is student staffed and the PIs change every semester.

Some of the other major requirements for a data collection/management system for the Studio includes ability to maintain an equipment queue, record training events and maintain updated equipment status. An equipment queue would allow users to virtually stand in line when there are fewer resources/tools than users. The system should alert users when they are next in queue and when the equipment is finally available for use. Since the Studio champions for the on-the–spot training (without needing to schedule training) by PIs for most tools, it was necessary to have a system that would electronically record these training events without requiring manual data entry. Such a system could help keep track of the date/time and trainer information, which could then help in conducing analysis on the training process for future improvements. Finally, having an online system to view the current health status of the tool could help users from across the campus to know if a tool is available or if they need to find alternate resources.

## METHODOLOGY

As mentioned earlier, SUMS was originally designed to gather equipment usage information and generate invoices for their usage. This system had access to the central Georgia Tech database and was capable to reach Georgia Tech RFID enables ID badges. Given the already existing infrastructure, SUMS was selected to be enhanced/modified in order to meet the specific for data collection in the Invention Studio. The following section presents how the requirements of the data collection system were incorporated using SUMS.

*SUMS Workflow*

SUMS is a browser-based system that utilizes RFID readers which are mounted on touchscreen kiosk computers. Kiosks are placed in different rooms/zones to display different categories of tools. SUMS uses the IP addresses of the kiosks to display a unique screen to users and PIs to log in, join/edit queues, and monitor equipment in that room. Figure 1 shows the backend SUMS' workflow used to manage user and equipment data.

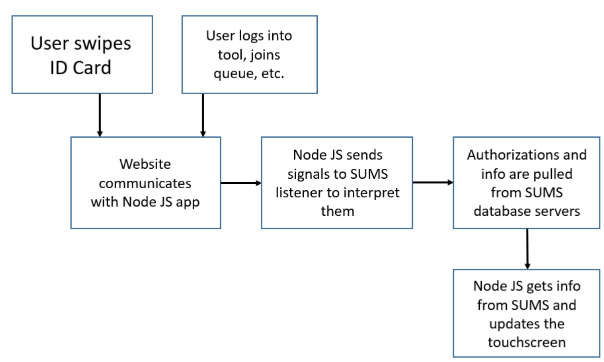


*Figure 1: SUMS workflow when a user wipes their ID at the kiosk.*

When a user initially swipes their card at a SUSM kiosk, logs into equipment, joins/leaves a queue, passes/fails a training requirement, or anything happens on a touchscreen, the touchscreen website communicates with a Node JS app that is downloaded and runs on each kiosk. Node JS is linked with a listener within the SUMS server that interprets signals coming from the touchscreen. Once the SUMS server receives the interpreted signals it gathers and updates its database and sends information back to the Node JS which then updates the touchscreen that the user sees. The SUMS database server is connected with the Georgia tech directory and can fetch information like the user's contact information as well as school affiliation, majors, etc.

*Login & Queueing System*

Figure 2 shows how the schematic of the SUMS' kiosk screen. Starting from left, user first selects an equipment to login, then sees past usages, and finally can add him/her self to the queue. PIs have additional feature change equipment status in the lower right.

Queuing system has three modes depending on the type of equipment. The first mode is a simple login and logout with multiple users allowed at a time. It is useful for an environment such as a woodworking shop where various readily available stock tools such as hand drills, hammers, and cutting tools are required to complete a job.

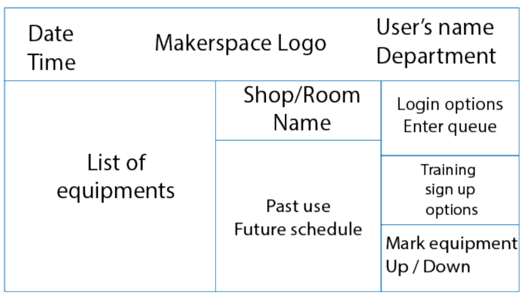


*Figure 1:Schematic of SUMS kiosk screen layout*

The second mode is single equipment queue. It is useful when only a single equipment of its kind is in the space. For example, if there is only a single waterjet available for use. Users will be added to a queue and notified when the last user logs out from the equipment. Figure 2 shows a queue example for Laser Cutter as seen by a PI.

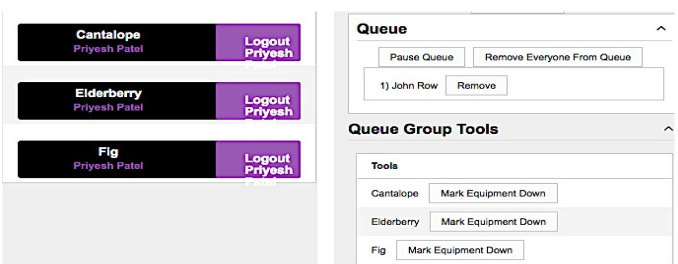


*Figure 2: Multiple tools, multiple login & queue, kiosk screenshot.*

The third mode is intended for multiple pieces of equipment in a single queue. This is used in situations where the space has many pieces of equipment of the same type such as 3D printers or laser cutters. The third mode will notify the next user when any one of the equipment is available which is determined by logging out of the last user. Figure 2 shows that 'John Row' is added to a queue after all 3 Laser cutters are in use by 'Priyesh Patel'.

The queue feature of SUMS is robust enough that if a piece of equipment is marked down it will automatically put the last user back in the queue if the user is currently "notified" to log in. The queue only allows a pre-set amount of time for the user to log into a piece of equipment before automatically removing the current user and notifying the next user to log in.

*Training Records*

The Invention Studio uses a checklist with several tests, each for a different room to train users to become a PI [5]. One of the important uses of SUMS is that it tracks users' progress through each test as they go through each checklist. SUMS gives PIs the ability to mark users pass or fail with every instance recorded by date, time, and name of the PI administering the test. PIs simply scan their ID and navigate to a particular checklist item. They are then prompted to scan the user's ID and make a pass/fail selection. Test results recorded can be accessed through the SUMS website by an interviewer when a user requests to become a PI. All users' records are only available to interviewers, SUMS administrators, and individual users themselves. Furthermore, only PIs can pass/fail a user. These restrictions are in place to give PIs and studio staff, power to train users and to accommodate existing Invention Studio culture.

*SUMS user roles*

A software system implementation is only possible if it is well integrated into an already existing and thriving culture. The Invention Studio historically have had two user types, PIS who are staffing the space and general users. For successful utilization of SUMS, an additional user type, 'developer' was necessary. Each user type has a different set of permissions and features available to them.

The developers have additional permissions for the background functionality and features accessible through the SUMS website. They can change any user's type to either a general user, a PI, or a developer. Additionally, they can give special permissions to certain individuals. Developers also have access to the data generated and ability to add or remove pieces of equipment from SUMS. The developers can also change the time delay of the auto removal from the queue.

The second user type is a PI. PIs staff the Invention Studio and have access to maintenance features on kiosks. One of these features is queue editing.  PIs can change users' positions or remove a user entirely in the queue. PIs can pause the queue to take manual control and clear the entire queue to make it ready for the next day. PIs also can mark a malfunctioning equipment down and back up once fixed. Figure 9 shows how a kiosk and a status screen looks when a queue is paused.

The third user type is a general user. Everyone in this group can use all pieces of equipment simply by logging in or joining a queue. The status screen is another feature of SUMS that helps the system to be more integrated with the existing structure of the invention studio. The status screen displays each queue in real time and the time remaining before auto removal of a user from a queue.

## RESULTS

### *Equipment Data*

The following graphs and charts are generated by SUMS and are available to download through the SUMS website, as well as excel files containing all raw data SUMS produces. The graph in figure 4 shows the log in count for February 2017. The left y-axis illustrates the total logins for all tools combined and the right y-axis (in green) shows the total logins for each tool (shown in different color bars) for the given period. The x-axis shows the weekly period throughout the month and states only the start date of the period on the label. The log in count also helps identify peak times; for example, last spring, the peak time was the week of January 23rd. The lowest log in count can also be identified, which was the week of March 23rd because of Spring Break.

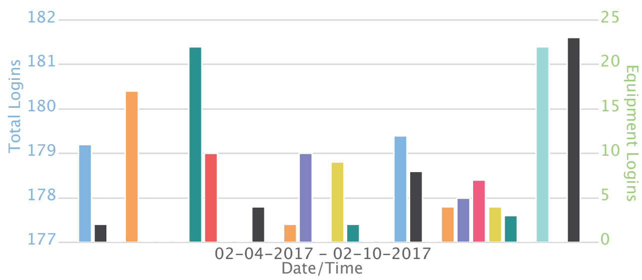


*Figure 4: Login count generated by SUMS for one week*

Another important figure SUMS generates is the pie chart that shows the percentage of usage for each tool. Table 2 shows the percentage of usage for each equipment throughout the month in the entire Invention Studio.

SUMS helps with identifying equipment down time, due to either malfunction or maintenance. This can help identify tools that need more maintenance or need to be replaced. To get a better sense of the capabilities of SUMS, an equipment report was generated for a specific set of equipment, 3D Printers. SUMS can generate a graph with the total logins and the equipment logins can be seen for each week of the semester.

*Table 2: Percentage of usage for all equipment for 02/2017.*

| Tool | Percentage of Usage |
|---|---|
| Wood Room | 32.9% |
| Waterjet | 3.3% |
| Metal Room | 2.3% |
| Machining Mall | 21.2% |
| Laser Cutters | 6.7% |
| 3D Printers | 32.4% |
| Electro lounge | 1.2% |

Figure 5 is also important for evaluating the performance as it shows total hours for each 3D printer (in green), the average hours used per user (in black), and the total number of unique users that logged in to the 3D printer in that period (in orange). It also shows the average hours per user, which can help us identify the size of the projects users are working on.

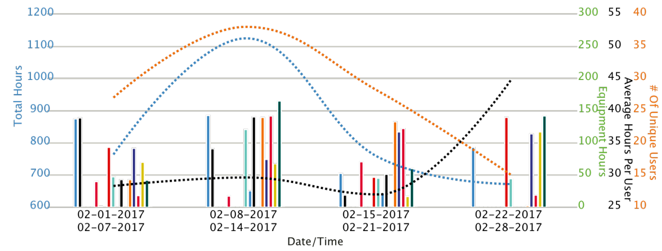


*Figure 5: Total usage hours for all 3D printers for February 2017.*

SUMS can also generate pie charts to identify the percentage of usage for each 3D printer; the ideal pie chart would have equal usage for all the 3D printers. The data generated for February 2017 shows that each printer usage ranges from 0.3%-7.5%. The goal is to get this range to be as small as possible. Furthermore, the total down time for each 3D printer helps identify not only when a printer breaks, but also when the filaments are running out for each 3D printers.

### *User Data*

SUMS gathers a lot of information about users since it is directly linked to the Georgia Tech directory, meaning the first time a user taps his ID on any of the Invention Studio kiosks they will be asked to read and accept the safety agreement. If the user accepts the safety agreement, they are added to the invention studio database and all the necessary information is then pulled directly from the registrar database. Through the SUMS website a list can be generated of all the users that signed the agreement and identify their standing, school, major, and as shown in figure 6, the number of new users for each semester.

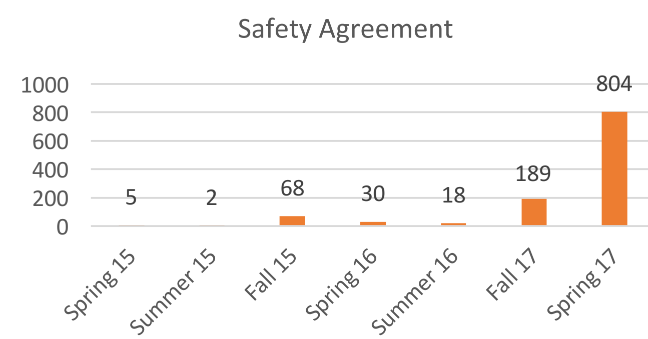


*Figure 6: Safety agreement history, generated from excel using SUMS database.*

## DISCUSSION

As presented in the Results' section, SUMS can easily gather user demography data due to its direct integration with the Institution's central user database. The data from SUMS shows that of all the users of the Invention Studio in the past few months, 85% of them were undergraduate students and the rest were graduate students.

Figure 7 and figure 8 show the distribution of schools and majors respectively based on number of users utilizing the Invention Studio. One should note that mechanical engineering has been removed from the major chart as it compromises 47% percent of the users in the space.

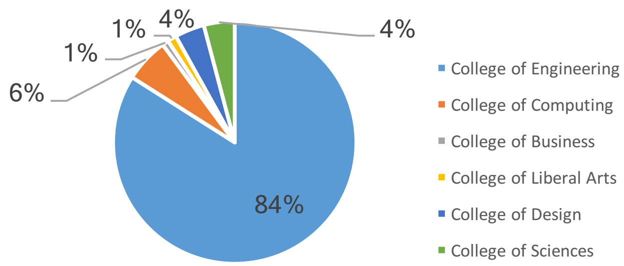


*Figure 7: Percentage of users from different colleges.*

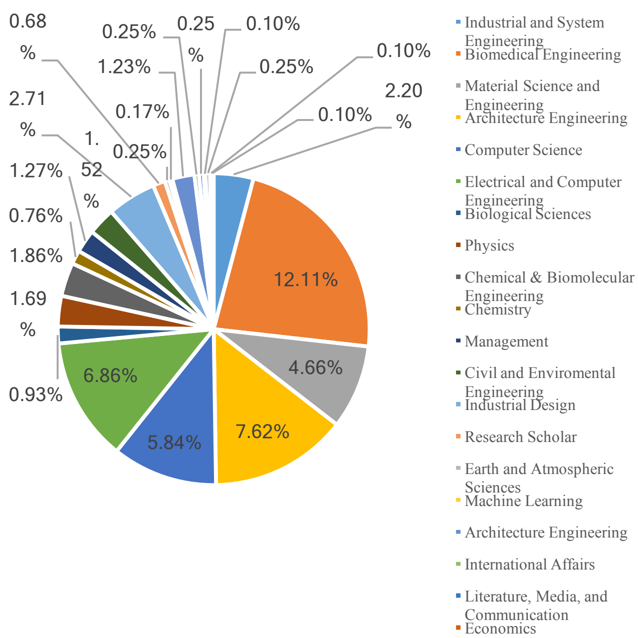


*Figure 8: Distribution of users from non-ME schools on campus (ME accounts for 47% not shown in this pie chart).*

*Future Improvements*

New features are constantly being worked on for SUMS. Some of which are buddy systems for more dangerous tools, maintenance schedule notifications, and a text message system for queue notifications. Additionally, it is important to note that SUMS has features to set up scheduled down times for tools, scheduled usages, and restrict time users can be logged into tools. However, these features are not currently needed in the Invention Studio.

A buddy system can be implemented to replace the current honor system for high-risk equipment such as the wood lathe. No user including a PI can use high-risk equipment unless they are in proximity to another user who is aware the tool is being used. SUMS can be used so that a user will not be able to log into a high-risk tool unless another user also logs into that tool. With ongoing use of SUMS, a significant amount of data will be collected. This data will make it easier for staff to estimate more realistic equipment maintenance schedules. These can include schedules for 3D print filament replacement, laser cutter lens replacement, or waterjet garnet cleanout.

A text messaging system, although not in SUMS, can be integrated with SUMS using a third party company, like Twilio, which offers services for text message notifications. The messages could be sent out in the form of a text message for queue notifications. This could provide faster delivery to the user compared to the email notification or live queue on the status screen.

## CONCLUSION

A well developed makerspace data management system needs to possess several capabilities. The system needs to collect useful equipment usage data that could help better allocate resources. It should have features to facilitate electronic record keeping of training certifications for users and provide a means to enable users to enter a queue for equipment in high demand. Finally, any data collection and management system should be easy and intuitive to access and use so that users and manages of the space spend more time in learning and sharing. The SUMS platform presented in this paper meets most of these requirements. However, in the spirit of continuous improvement, the authors continue to solicit active feedback from users and PIs to further the development of this system.

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