A System to Support the Tracking of Laptops/Equipment Loaner Program for Students and Faculty of the College of Engineering, Computing, and Applied Sciences (CECAS)
- Final Report -

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Executive Summary

The students and faculty of Clemson University's College of Engineering, Computing, and Applied Sciences (CECAS) occasionally need laptops or/and computing equipment for some time, for instance, due to their laptops being out of order or if they require equipment for some particular purposes. To meet the needs of such students and faculties, the College established a manual, paper-based laptop and equipment loaner system in 2020. However, the existing system has many limitations. These include (i) a lack of a tracking mechanism to manage inventory and loaning status, (ii) the possibility of paper forms getting occasionally lost, leading to the loss of university assets, and (iii) cases of delays in getting approvals from staff.

Our team was constituted to develop a new system to manage the laptop/equipment loaner program. Following Ulrich & Eppinger's methodology, we developed a mission statement and conducted a customer needs analysis, generating thirteen primary and twenty-nine secondary user needs. In addition, the needs' relative importance was established, and some targets were specified. Through the target specifications, twenty-two metrics were developed. Moreover, we identified three competitors and used them to create competitive benchmarking. Based on the benchmarking information, ideal and marginally acceptable metric values for the new system were set. Furthermore, four personas were created to represent the stakeholders.

The team generated four concepts. The concepts were subjected to rigorous screening and scoring iteratively. This led to the selection of a concept that was combined with some features from one of the remaining three concepts. A working prototype of the refined concept was then developed. The new system was tested with actual users to determine how well the system satisfies the design specifications and the users' needs. Based on the test findings, the system

was iteratively refined. A performance evaluation of the new laptop/equipment loaner system revealed performance values that satisfied the ideal threshold for each of the metrics. To fully develop the final concept, we estimated it would cost $6,675.

Considering all the concept variants, we recommend the stakeholders implement our final design as it addresses all the primary needs identified. A final coding of the front- and back-end is required for the website to be operational and functional. This, we believe, would be done once the project report and user interface are handed over to the CORE staff.

1. Introduction

This project was initiated to address the inefficiencies of the current manual process of the College of Engineering, Computing, and Applied Sciences (CECAS) laptop and equipment loaner system. The paper-based system made keeping an inventory of equipment and loan records difficult. It was also associated with the possibility of request forms going missing. Due to these issues, request approvals often took longer than necessary.

Our development team sought to address the limitations of the existing system. The development of the new system was divided into four phases. In the first phase of the system, a mission statement and customer-selection matrix were developed. Through a series of semi-structured interviews with 11 stakeholders and affinity mapping of the needs generated from the results of the interviews, a total of thirteen primary and twenty-nine secondary user needs were identified. Furthermore, the relative importance of the needs was established via a customer survey.

The second phase of the project produced some target specifications. A total of twenty-two metrics were developed. Based on these metrics, a needs-metrics matrix was composed. Three competitors were identified and considered in developing a competitive benchmarking. The benchmarking information was used to set ideal and marginally acceptable metric values for the new system.

In the third project phase, four personas were created after mapping the interviewees based on some identified behavioral and demographic variables. Moreover, four concepts were generated, and through a series of iterations, the concepts were screened and scored. Ultimately,

the concept with the highest score was selected for further development. The chosen concept was refined by combining some features of the concept with the second-highest score.

The goals of this last project phase are to (i) develop a detailed prototype of the selected concept, (ii) test the developed prototypes with actual users to determine how well the system satisfies the design specifications and the users' needs, (iii) iteratively refine the system based on the test results, and (iv) deliver the finalized product to CECAS.

This report describes the constituent activities of processes involved in phases one to three of the project and presents the project's final phase. The rest of the report is organized as follows: section 2 describes the existing situation of the CECAS laptop and equipment loaner system. The remaining parts of the report are focused on the new system. In section 3, the mission statement is presented. Section 4 presents the customer needs analysis. In section 5, the product specifications are described. Section 6 discusses the development of personas. The concept generation and selection processes are presented in sections 7 and 8, respectively. Further, the user testing and refinement process are described in section 9. A detailed system design is presented in section 10; the system is evaluated, and the results are described in section 11. Sections 12 and 13 contain the cost analysis and final recommendations, respectively. The implementation plan is discussed in section 14. The last section summarizes and concludes the report.

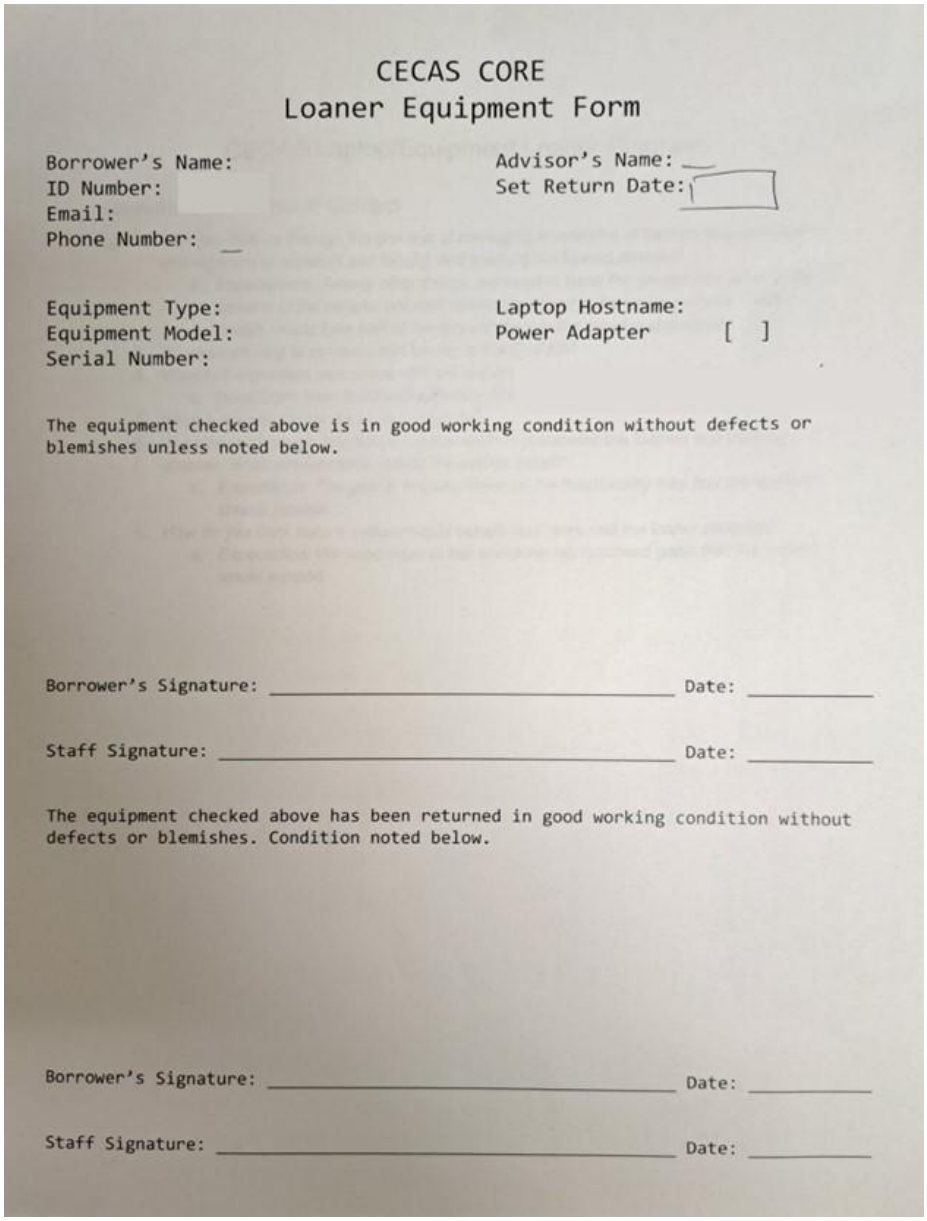
2. Current State of the System

The existing equipment loaning system was established in 2020. Students or faculty usually approach the Computing Operations and Research Enterprise (CORE) counter to request a loaner laptop if their primary laptop is out of order or if they need one for a specific requirement, such

as sharing a presentation or performing a study. Other supporting equipment is also loaned on a need basis. A paper-based form (Figure 2.1) is filled in with basic user information, available equipment information (type, model no., serial no., and hostname), and staff approvals, after which a piece of equipment, e.g., a laptop, is assigned. Once the user has completed the usage, they return to the counter, fill in the return section of the same paper form, and return the laptop after the staff has checked the equipment for any defects or blemishes.

The main issues faced by the CORE team for the existing system are:

i. Lack of a tracking mechanism to manage inventory and loaning status.
ii. The possibility of paper forms getting occasionally lost, leading to the loss of university assets.
iii. Delays in getting approvals from staff or faculty if unavailable.



CECAS CORE
Loaner Equipment Form

Borrower's Name:
ID Number:
Email:
Phone Number:

Advisor's Name:
Set Return Date:

Equipment Type:
Equipment Model:
Serial Number:

Laptop Hostname:
Power Adapter [ ]

The equipment checked above is in good working condition without defects or blemishes unless noted below.

Borrower's Signature: _____ Date: _____

Staff Signature: _____ Date: _____

The equipment checked above has been returned in good working condition without defects or blemishes. Condition noted below.

Borrower's Signature: _____ Date: _____

Staff Signature: _____ Date: _____

Figure 2.1. A photograph of the existing paper-based equipment loaner form

3. Mission Statement

3.1. Product Description

A system that supports effective requesting, tracking, and managing of loaner laptops and supporting equipment for students and faculty of the College of Engineering, Computing, and Applied Sciences (CECAS).

3.2. Benefit Proposition

i. It makes it easier for users to request loaner laptops
ii. Caters to user's specific software and hardware needs
iii. Reduces waiting time for loan requests

3.3. Key Business Goals

i. Improve user satisfaction by 45%
ii. Reduce processing time by 30%
iii. Reduce occurrences of unreturned laptops and equipment by 100%
iv. Improve analytics and report generation capability by 70%
v. Target deployment in 3 months

3.4. Target Markets

i. Primary market: College of Engineering, Computing and Applied Sciences at Clemson University
ii. Secondary market: Other colleges at Clemson University

3.5. Assumptions and Constraints

i. Users use their Clemson credentials to log in to the system
ii. Users have full access to digital devices and internet connectivity

iii. Applies to current students/faculty only

3.6. Stakeholders

i. CECAS students

ii. CECAS faculty

iii. CECAS staff

iv. Director of CECAS CORE Computing

v. Assistant Director of CECAS CORE Computing

vi. Clemson Computing and Information Technology (CCIT) staff

3.7. Customer Selection Matrix

After identifying the primary market and the list of stakeholders, a customer selection matrix was built. In this project, as CECAS students are prioritized as lead users, we selected more students than other stakeholders to understand their needs better.

Table 3.1: Customer selection matrix

	Students	**Staff**	**Faculty**	**Director of CECAS CORE computing**	**Assistant Director of CECAS CORE computing**	**CCIT staff at Library**
Clemson University College of Engineering, Computing, and Applied Sciences (CECAS)	5	2	1	1	1	1
Other colleges within Clemson University	-	-	-	-	-	-

4. Customer Needs Analysis

We conducted semi-structured interviews with 11 stakeholders based on the customer selection matrix to elicit customer needs. The interviews were done in person, in the customer's environment, and online via Zoom and voice chats.

For student stakeholders, the plan was to interview CECAS students who had used the existing system. Regrettably, it was impossible to identify such students due to confidentiality issues. Hence, we interviewed students who had never used the system. However, efforts were made to familiarize the students with the system. During the interview, a student is shown the paper-based loaner equipment form. Further, we provide a detailed description of the loaning process. The interview prompts included, among other things, questions on what the stakeholders liked and disliked about the existing system and areas of improvement for the new system. After obtaining permission from the stakeholders, we recorded the interview sessions. The recorded data was transcribed. We analyzed the data by extracting customer needs focusing on what the product must do. An example of a question, a customer response, and the interpreted needs are presented in Table 4.1.

Table 4.1: Customer data template.

Question prompt	**Customer statement**	**Interpreted need**
What do you dislike about the current loaning system?	"Impossible to know where the equipment is without touching a piece of paper, and I am not in the office all the time."	The system is easy to access
What improvements can you suggest for the new system?	"I was unaware that such a system existed for faculty. It will be good to integrate this into the CECAS website."	The system creates awareness among current and new students/faculty about the service

4.1. Affinity Mapping

Each of the needs statements was written on a separate card. Figure 4.1 presents a snapshot of the needs pasted on a whiteboard. We eliminated the redundant needs. After that, the needs were grouped based on affinity, i.e., their similarity in meaning. Each group was then labeled. A total of 13 groups were created (see Figure 4.2). The group headers make up the primary needs, while the needs statements in the cards constitute the secondary needs. Table 4.1 presents the list of primary and secondary needs.

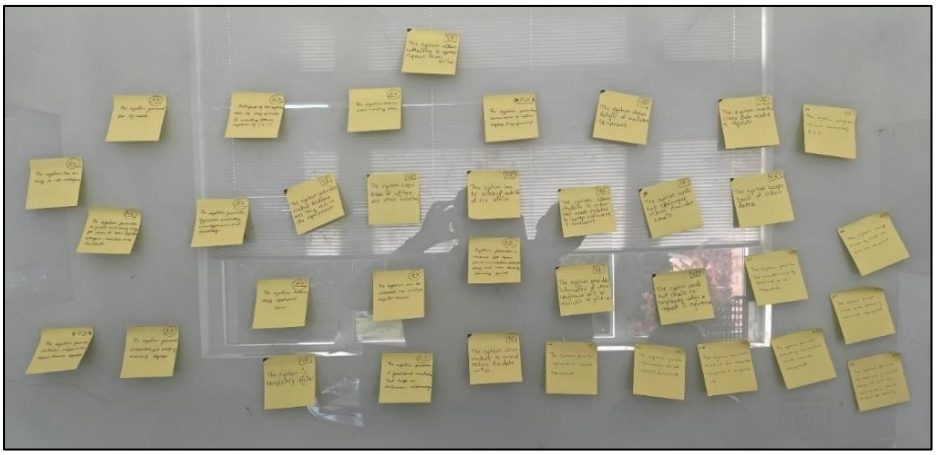


Figure 4.1. Identified needs statements presented in cards

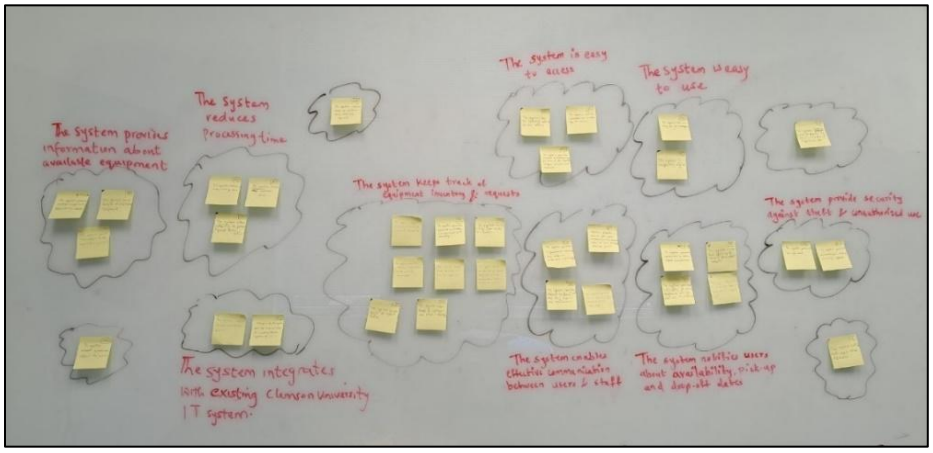


Figure 4.2. Affinity mapping of customer needs

Table 4.1: Primary and secondary needs. The 13 primary needs are emboldened

1	**The system provides information about available equipment**
1.1	The system provides detailed information about loaner laptops
1.2	The system shows details of available equipment
1.3	The system provides information about laptops/equipment
2	**The system reduces waiting time for staff and users**
2.1	The system reduces user waiting time
2.2	The system reduces equipment approval time
2.3	The system allows authorities to approve request forms online
3	**The system enables users to extend their loaning period**
4	**The system is easy to access**
4.1	The system can be accessed outside the office
4.2	The system can be accessed by multiple digital devices
4.3	The system provides a quick and easy way for users to loan laptops and equipment
5	**The system is easy to use**
5.1	The system has an easy-to-use interface
5.2	The system is completely digital
6	**The system enables users to provide their specific software and hardware requirements**
7	**The system creates awareness about the loaning service**
8	**The system integrates with existing loaning systems within the university**
8.1	The system integrates with Clemson University's SSO
8.2	The interface of the system can be very similar to existing loaning system of CCIT
9	**The system keeps track of equipment inventory and requests**
9.1	The system keeps track of the returned equipment
9.2	The system provides inventory information about loaned equipment
9.3	The system provides efficient inventory management and tracking
9.4	The system keeps track of staff who give out equipment
9.5	The system stores data related to requests

9.6	The system provides an overview of loaned equipment with the corresponding loaned student or faculty
10	**The system enables effective communication between users and staff**
10.1	The system provides a feedback mechanism that helps in continuous improvement
10.2	The system provides a means for open communication between staff and users during the loaning period
10.3	The system provides status feedback to students once they return the equipment
10.4	The system provides for maintenance of equipment to be requested
11	**The system notifies users about availability, pick up, and drop off dates**
11.1	The system provides reminders to return laptops/equipment
11.2	The system sends out equipment return reminder emails
11.3	The system provides information on when equipment will be available for pick up
11.4	The system stipulates a deadline for requested equipment to be picked up
12	**The system provides security against theft and unauthorized usage**
12.1	The system prevents loss of assets
12.2	The system prevents unauthorized usage of university laptops
13	**The system notifies staff about new requests**

4.2. Important Needs Survey

The surveys were conducted to establish the relative importance of the customers' needs. We sent the survey link by email to all the stakeholders who were chosen for interviews. The result of the survey was useful as we moved to the stage of design specification. Figure 4.3 shows an example of a survey question. The survey includes all 13 primary needs identified from affinity mapping.

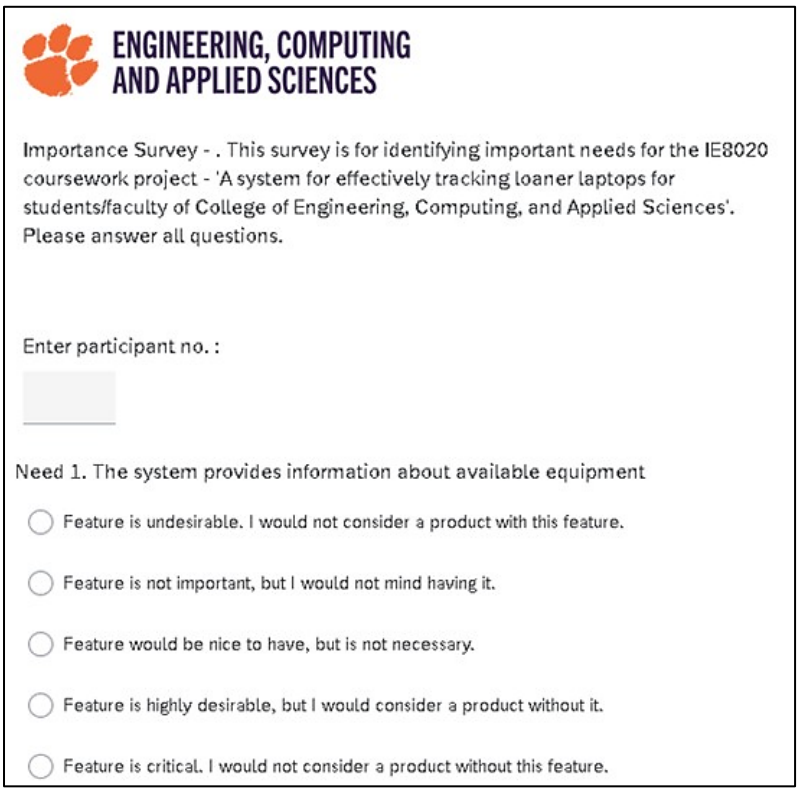


Figure 4.3. Snapshot of the survey to establish the relative importance of the needs.

4.3. Relative Importance of Needs

A sense of relative importance of needs is essential to make tradeoffs and allocate resources in designing the product correctly. Table 4.2 presents the needs with their corresponding relative importance based on the email survey responses from all the stakeholders. The needs are ranked based on the criticality criteria: 5 being the most critical or the must-haves and 1 being the least critical but nice to have.

Table 4.2: Customer needs for the laptop loaner system and their relative importance

No		Needs	Imp.
1	The system	provides information about available equipment	4
2	The system	reduces waiting time for staff and users	1
3	The system	enables users to extend their loaning period	2
4	The system	is easy to access	4
5	The system	is easy to use	5
6	The system	enables users to specify their software/hardware requirements	1
7	The system	creates awareness about the loaning service	1
8	The system	integrates with the existing Clemson University IT system	1
9	The system	keeps track of equipment inventory and requests	3
10	The system	enables effective communication between users and staff	2
11	The system	notifies users about availability, pickup, and drop-off dates	4
12	The system	provides security against theft and unauthorized usage	4
13	The system	notifies staff about new requests	4

5. Product Specifications

5.1. Metrics Preparation

We developed a series of metrics to provide technically meaningful and satisfactory customer goals. The goals metric covered a range of issues, including performance, quantity, time scales, customers, and users. Throughout the process, we were guided by the needs of the customer and the demands of the market. Table 5.1 presents the list of metrics for customer needs. The relative importance of each metric and the units for the metric are also shown. “Subj.” is an abbreviation indicating that a metric is subjective.

Table 5.1: List of metrics for laptop loaner system.

Metric No.	Need No.	Metric	Imp	Units
1	1,6	Time taken to find information about available equipment by 5 users	4,1	s
2	2	Average time to complete a loan request by 5 users	1	s
3	2	Average time to approve a loan request by 2 staff members	1	s
4	3	Time to complete loan extension request by 5 users	2	s
5	4	Maximum time to log in to the system using desktop, mobile, and tablet by 7 users	4	s
6	5	Average time to complete 3 tasks by 7 users	5	s
7	5	Average error rate in completing 3 tasks by 7 users	5	%
8	5	Average completion rate of 3 tasks by 7 users	5	%
9	6	Average time to select software specification by 5 users	1	s
10	6	Average time to select hardware specification by 5 users	1	s
11	7	Creates awareness about the loaning service	1	Subj.
12	8	System integrates with the existing Clemson University IT system	1	Binary
13	9	Average time to access the equipment inventory by 3 staff members	3	s
14	9	Average time to access the list of requests by 3 staff members	3	s
15	10	Compliance with VPN / Information protection protocol	2	Binary
16	10,11	Frequency of sending drop-off reminders in a week	2,4	Count
17	11	Notifications delivery rate for equipment pickup date	4	%
18	11	Notification delivery rate for equipment drop-off date	4	%
19	12	Provides security against theft and unauthorized usage	4	Subj.
20	13	Notification delivery rate for equipment request	4	%
21		Development cost		US $
22		Maintenance cost per month		US $
23	4,5	Compliance with ADA guidelines	5	Binary

5.2. Needs-Metrics Matrix

Based on the list of metrics, we composed a needs-metrics matrix to further highlight the relationship between needs and metrics. The needs-metrics matrix is presented in Figure 5.1.

	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Metric	Time taken to find information about available equipment	Average time to complete a loan request	Average time to approve a loan request	Time to complete loan extension request	Maximum time to log in to system using desktop, mobile, and tablet	Average time to complete 3 tasks	Average error rate in completing 3 tasks	Average completion rate of 3 tasks	Average time to select software specification by 5 users	Average time to select hardware specification by 5 users	Creates awareness about the loaning service	System integrates with the existing loaning systems within the univers	Average time to access the equipment inventory by 3 staff members	Average time to access the list of requests by 3 staff members	Compliance to VPN / Information protection protocol	Frequency of sending reminders during loaning period	Notifications delivery rate for equipment pickup date	Notification delivery rate for equipment drop-off date	Provides security against theft and unauthorized usage	Notification delivery rate for equipment request	Development cost	Maintenance cost per month
1	The system provides information about available equipment	O																					
2	The system reduces waiting time for staff and users		O	O																			
3	The system enables users to extend their loaning period				O																		
4	The system is easy to access					O																	
5	The system is easy to use						O	O	O														
6	The system enables users to provide their software/hardware requirements while requesting	O								O	O												
7	The system creates awareness about the loaning service											O											
8	System integrates with the existing Clemson University IT system												O										
9	The system keeps track of equipment inventory and requests													O	O								
10	The system enables effective communication between users and staff															O	O						
11	The system notifies users about availability, pickup and drop off dates																O	O	O				
12	The system provides security against theft and unauthorized usage																			O			
13	The system notifies staff about new requests																				O		

Figure 5.1. Needs-metrics matrix

5.3. Competitive Benchmarking

Three competitors were considered for a competitive benchmarking process. The first competitor is the current system at CECAS; the second competitor is the Clemson Computing & Information Technology (CCIT) operating in the Robert Muldrow Cooper Library at Clemson

University[1], and the third competitor is the computing equipment loaning program at Massachusetts Institute of Technology (MIT)[2].

Table 5.2: Competitive Benchmarking

Metric Nos.	Need Nos.	Metric	Imp	Units	Competitor 1 (Current Process)	Competitor 2 (CCIT)*	Competitor 3 (MIT) *
1	1,6	Average time taken to find information about available equipment by 5 users	4,1	s	300	180	120
2	2	Average time to complete a loan request by 5 users	1	s	600	360	300
3	2	Average time to approve a loan request by 2 users	1	s	<60	<60	<60
4	3	Time to complete loan extension request by 5 users	2	s	300	<60	<60
5	4	Maximum time to log in to system using three different devices (Desktop, Mobile, Tablet)	4	s	0	<10	<10
6	5	Average time to complete three tasks	5	s	600	300	240
7	5	Average error rate in completing 3 tasks by 5 users	5	%	30	10	5
8	5	Average completion rate of three tasks	5	%	100	100	100
9	6	Average time to select software specification by 5 users	1	s	N/A	N/A	90

[1] Clemson University. Clemson Computing & Information Technology. https://ccit.clemson.edu/services/

[2] Massachusetts Institute of Technology (MIT) Information Systems and Technology. Computing Equipment Loan Program. https://ist.mit.edu/loaner-equipment

10	6	Average time to select hardware specification by 5 users	1	s	N/A	N/A	90
11	7	Creates awareness about the loaning service	1	Subj.	No awareness	Yes	Yes
12	8	System integrates with the existing Clemson University IT system	1	Binary	No	Yes	Yes
13	9	Average time to access the equipment inventory by 3 staff members	3	s	1800	600	480
14	9	Average time to access the list of requests by 3 staff members	3	s	1800	600	480
15	10	Compliance with VPN / Information protection protocol	2	Binary	No	Yes	Yes
16	10, 11	Frequency of sending drop-off reminders in a week	2,4	Count	0	0	2
17	11	Notifications delivery rate for equipment pickup date	4	%	0	100	100
18	11	Notification delivery rate for equipment drop-off date	4	%	0	100	100
19	12	Provides security against theft and unauthorized usage	4	Subj.	No	5	5
20	13	Notification delivery rate for equipment request	4	%	0	100	100
21		Development cost		US $	Unknown	Unknown	Unknown
22		Maintenance cost per month		US $	Unknown	Unknown	Unknown
23	4,5	Compliance with ADA guidelines	5		Yes	Yes	Yes

5.3.1. Competitive Benchmarking Table Description

5.3.1.1 Metric Number 11

This metric assesses the system's capability to create awareness about the loaning program in respective markets. Here, the current process does not provide students with any form of awareness about the loaning program. CCIT and MIT provide information regarding their programs to their respective stakeholders through their websites.

5.3.1.2 Metric Number 19

This metric assesses the system's capability to provide security against theft and unauthorized usage. The current system does not have any means to provide security against theft. The CCIT loaning program offers a sense of security against theft as the user only receives this service if they give their laptop/equipment to CCIT for repair. MIT's loaning program also provides a sense of security against theft; the user can get charged for unauthorized usage or extend the period.

5.4. Setting Target Specifications

In this step, competitive benchmarking information was processed to set the target values for each metric. The ideal value is the best result the project team hopes for. The marginally acceptable value is the metric value that would barely make the product commercially viable. Both targets helped guide the upcoming concept generation and selection stages and refining the specifications. All the target specifications are listed in Table 5.3.

Table 5.3: Target Specifications.

Metric Nos.	Need Nos.	Metric	Imp	Units	Marginal Value	Ideal Value
1	1,6	Time taken to find information about available equipment by 5 users	4,1	s	<120	<60
2	2	Average time to complete a loan request by 5 users	1	s	<300	<300
3	2	Average time to approve a loan request by 2 staff members	1	s	<60	<60
4	3	Time to complete loan extension request by 5 users	2	s	<60	<60
5	4	Maximum time to log in to the system using three different devices (Desktop, Mobile, Tablet)	4	s	<10	<10
6	5	Average time to complete 3 tasks by 7 users	5	s	<240	<180
7	5	Average error rate in completing 3 tasks by 7 users	5	%	<5	0
8	5	Average completion rate of 3 tasks by 7 users	5	%	100	100
9	6	Average time to select software specification by 5 users	1	s	<90	<60
10	6	Average time to select hardware specification by 5 users	1	s	<90	<60
11	7	Creates awareness about the loaning service	1	Subj.	Yes	Yes
12	8	System integrates with the existing Clemson University IT system	1	Binary	Yes	Yes
13	9	Average time to access the equipment inventory by 3 staff members	3	s	<480	<180
14	9	Average time to access the list of requests by 3 staff members	3	s	<480	<180

15	10	Compliance with VPN / Information protection protocol	2	Binary	Yes	Yes
16	10,11	Frequency of sending drop-off reminders in a week	2,4	Count	>2	>2
17	11	Notifications delivery rate for equipment pickup date	4	%	100	100
18	11	Notification delivery rate for equipment drop-off date	4	%	100	100
19	12	Provides security against theft and unauthorized usage	4	Subj.	>5	>5
20	13	Notification delivery rate for equipment request	4	%	100	100
21		Development cost		US $	<9000	<7000
22		Maintenance cost per month		US $	<500	<300
23	4,5	Compliance with ADA guidelines	5	Binary	Yes	Yes

6. Personas

6.1. Importance of Personas

The purpose of a persona is to show an actual representation of users' needs and goals. It helps to better understand the potential users' demographics such as environment, frustrations, behaviors, and what they intend to achieve. This enables us to define and include all the features in the final product along with developing documentation and building consensus.

6.2. Persona Development

To create a persona, we mapped the interviewees to variables and identified patterns to group all the interviewees based on different behavioral patterns, as presented in Figure 6.1. We followed the standard nine-step approach which included dividing interviewees by role, clarifying distinctions and adding details, defining goals, identifying behavioral and demographic variables, identifying patterns, grouping, and prioritizing personas. In behavioral variables, we considered

mental models, attitude towards their task, familiarity with technology, and other aspects, while in demographic variables, we considered age, education, family members, etc.

For this project, we created four personas based on each type of stakeholder - student, faculty, Computing Operations and Research Enterprise (CORE) staff and Clemson Computing and Information Technology (CCIT) staff. A student persona is illustrated in Figure 6.2. Other personas are presented in Appendix A.

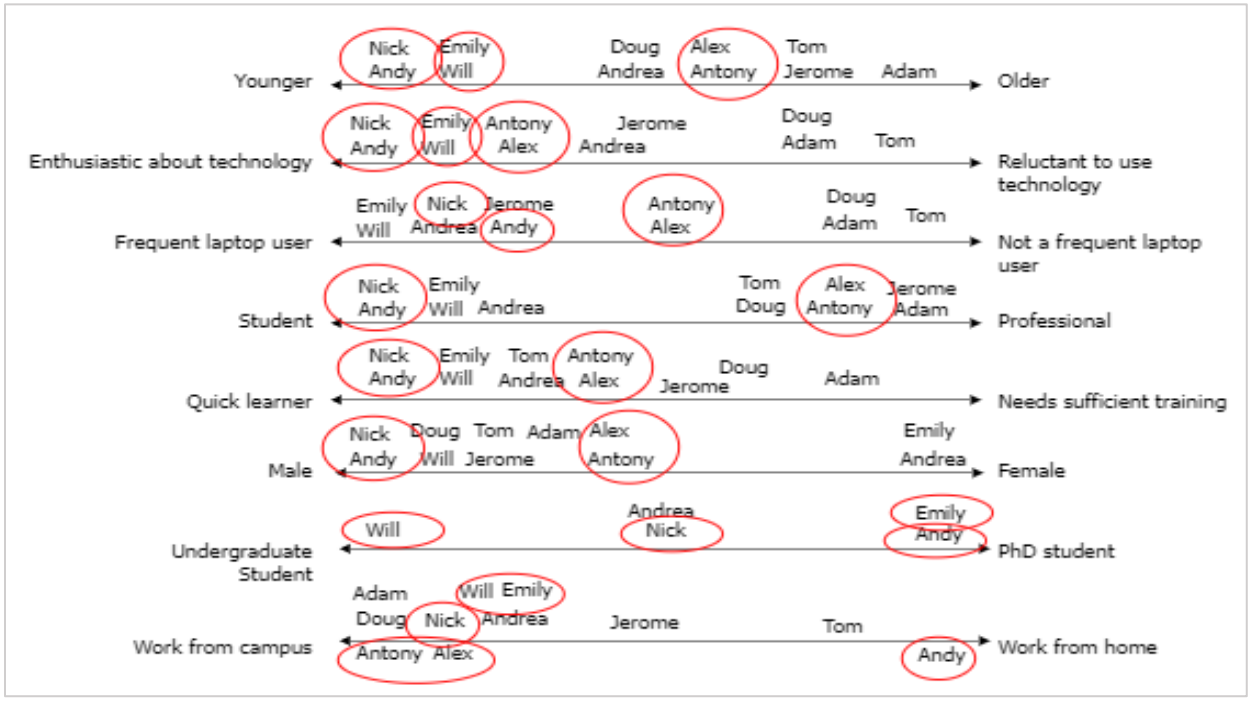


Figure 6.1. Mapping interviewees

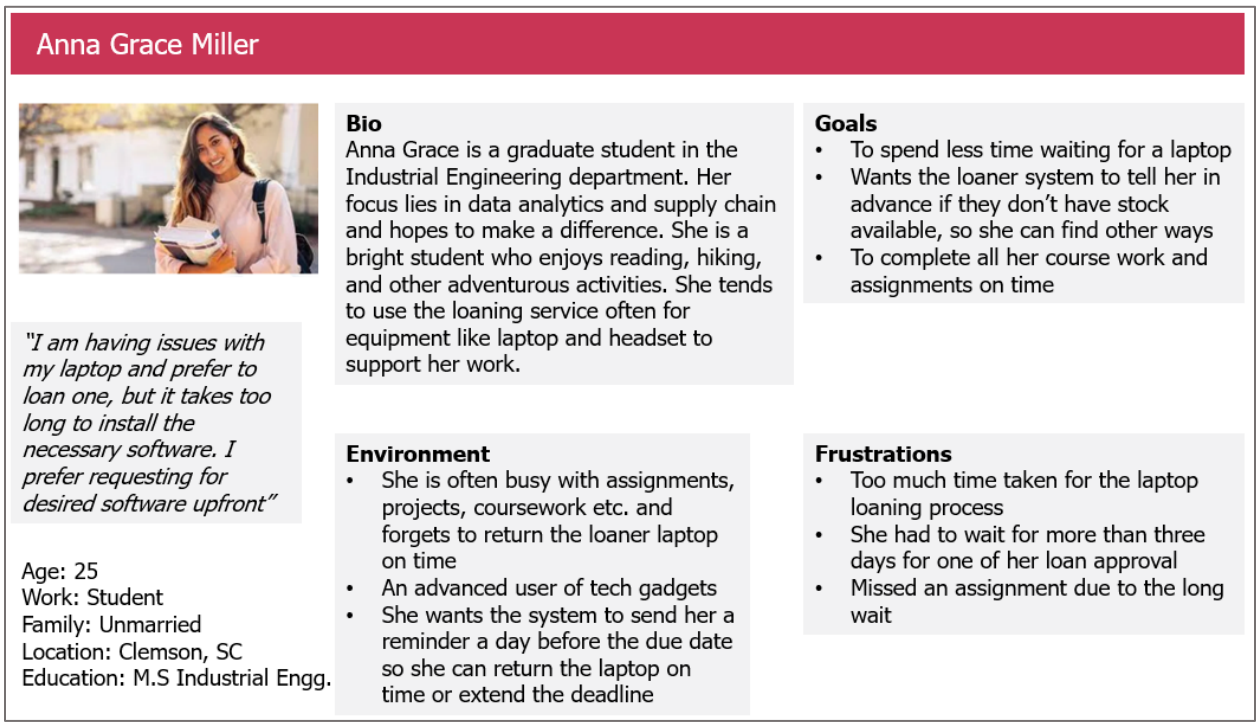


Figure 6.2. Student persona

7. Concept Generation

The quality of the underlying concept has a significant impact on a product's success. Early in the development process, thorough alternative investigation lessens the possibility of the team stumbling upon a better concept too late in the development process or a competitor introducing a product that is vastly superior to the one the team is working on. We followed the concept generation process recommended by Ulrich and Eppinger (2016) to generate our concepts.

7.1. Problem Decomposition: Function Diagram

In the first phase of the concept generation process—clarifying the problem—we used the customer needs list, mission statement, and target product specifications to develop a general understanding of the problem. Based on this, we further decomposed the problem into simpler

sub-problems related to a sequence of user actions. Using these actions, we developed a function diagram presented in Figure 7.1.

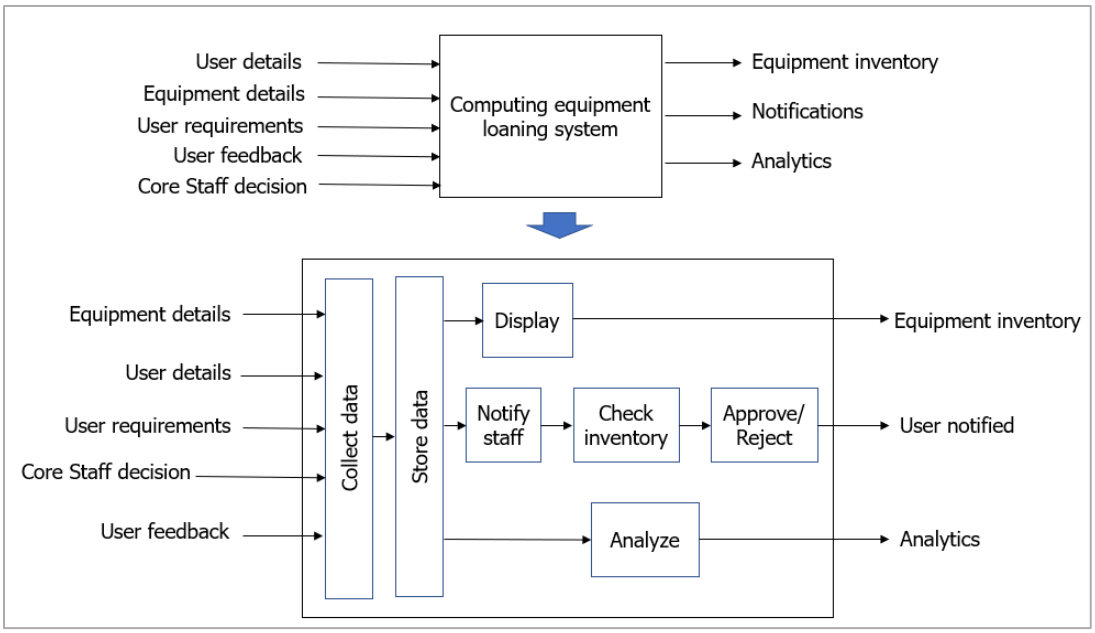


Figure 7.1. Function diagram

7.2 Concept Generation process

We developed multiple concepts based on the user needs list and function diagram by means of simple paper sketches, semi-detailed PowerPoint documents, and textual descriptions to generate ideas. Each team member produced at least ten concepts of the system sub-functions and eventually came up with one concept each for the entire system. The concept variants generated are presented in Appendix B.

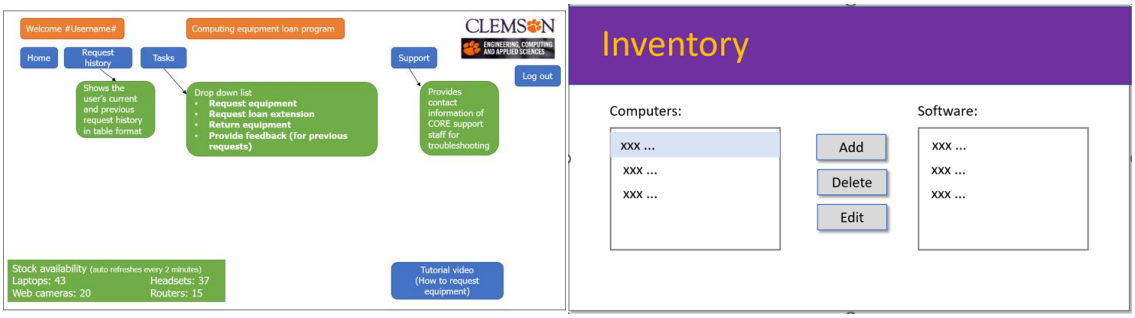


Figure 7.2. Examples of initial concepts

8. Concept Selection

In this step, we evaluated concepts in terms of customer needs and other important criteria. We compared strengths and weaknesses of the concepts and selected a couple of them for further investigation, testing and development.

8.1. Concept Screening

In this step, we followed the concept screening method to choose better concepts. The selection criteria are chosen from the primary needs identified during phase 1. The reference (REF) concept is the existing paper-based computer loaning system. Since all the concepts were better than the reference concept, as shown in Table 8.1, we proceeded to the concept scoring process.

8.2. Concept Scoring

In this iteration, we decided to perform the concept scoring technique. Here, the weights for the primary needs were assumed based on the importance rating survey collected during phase 2. The team discussed the ratings before assigning them to the concepts where “1” is the least score, and “5” is the highest score. The rating was multiplied by the weight to get the weighted score. For example, 5 x 0.12 = 0.59. We chose concept “A” to develop further. Here, some features from

concept “C” were added to concept “A,” and the concept chosen for further development is Concept “A+.”

Table 8.1: Concept screening

		Concept Variants				
No.	**Selection Criteria**	**A**	**B**	**C**	**D**	**REF**
1	The system provides information about available equipment	+	+	+	+	0
2	The system enables users to extend their loaning period	+	+	+	+	0
3	The system enables users to provide their software/hardware requirements while requesting	+	+	+	+	0
4	The system integrates with CU's log-in system	+	+	+	+	0
5	The system keeps track of equipment inventory and requests	+	+	+	+	0
6	The system notifies users about availability, pickup, and drop-off dates	+	+	+	+	0
7	The system notifies staff about new requests	+	+	+	+	0
8	The system is easy to Use	+	+	+	+	0
9	Ease of development	-	-	-	-	0
10	Cost of development	-	-	-	-	0
	Pluses	8	8	8	8	
	Sames	0	0	0	0	
	Minuses	2	2	2	2	
	Net	6	6	6	6	
	Rank	1	2	3	4	
	Continue	Y	Y	Y	Y	

Table 8.2: Concept scoring (iteration 1)

No.	Selection Criteria	Weights	Concepts R= Rating; WS= Weighted Score							
			A		B		C		D	
			R	WS	R	WS	R	WS	R	WS
1	The system provides information about available equipment	12 %	5	0.59	3	0.35	4	0.47	2	0.24
2	The system enables users to extend their loaning period	6 %	5	0.29	3	0.18	1	0.06	3	0.18
3	The system enables users to provide their software/hardware requirements while requesting	2 %	5	0.15	3	0.09	5	0.15	1	0.03
4	The system integrates with CU's log-in system	2 %	5	0.15	3	0.09	5	0.15	3	0.09
5	The system keeps track of equipment inventory and requests	9 %	4	0.35	1	0.09	5	0.44	3	0.26
6	The system notifies users about availability, pickup, and drop-off dates	12 %	5	0.59	2	0.24	4	0.47	2	0.24
7	The system notifies staff about new requests	12 %	5	0.59	2	0.24	3	0.35	2	0.24
8	The system is easy to Use	15 %	5	0.74	5	0.74	5	0.74	5	0.74
9	Ease of development	15 %	3	0.44	4	0.59	4	0.59	4	0.59
10	Cost of development	15 %	3	0.44	5	0.74	4	0.59	4	0.59
	Total score		4.32		3.32		4.00		3.18	
	Rank		1		3		2		4	
	Continue?		Develop		No		No		No	

Table 8.3: Concept scoring (iteration 2)

No	Selection Criteria	Weights	Concepts	
			A+	
			Rating	Weighted Score
1	The system provides information about available equipment	12 %	5	0.59
2	The system enables users to extend their loaning period	6 %	5	0.29
3	The system enables users to provide their software/hardware requirements while requesting	2 %	5	0.15
4	The system integrates with CU's log-in system	2 %	5	0.15
5	The system keeps track of equipment inventory and requests	9 %	5	0.44
6	The system notifies users about availability, pickup, and drop-off dates	12 %	5	0.59
7	The system notifies staff about new requests	12 %	5	0.59
8	The system is easy to Use	15 %	5	0.74
9	Ease of development	15 %	4	0.59
10	Cost of development	15 %	4	0.59
		Total score		4.71
		Rank		1
		Continue?		Yes

8.3. Prototype Development and Preview

We developed a working prototype of concept A+ using the Axure RP 10 prototyping tool. Screenshots of the concept that include the login page, home page, equipment request page, request completion page, and notification page are presented in Figure 8.1.

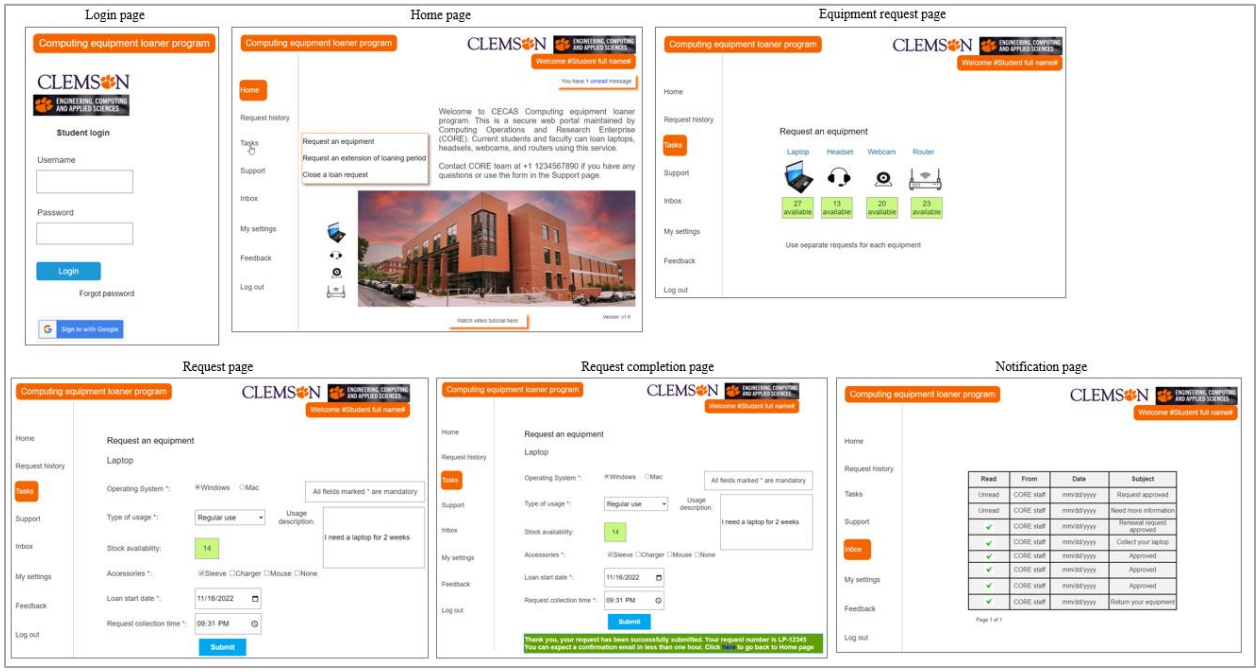


Figure 8.1. Preview of concept A+

9. User Testing and Refinement

The developed prototype was subjected to extensive user testing. Eight users, including five CECAS students, one CECAS faculty, and two CECAS CORE staff tested the system and provided feedback. All the user testing was done physically.

9.1. Testing Procedure

The steps followed to test the prototype system are presented in Figure 9.1. First, the system was introduced to the user. After that, the user was asked to perform some tasks. The tasks depended on the user category. For CECAS students and faculty, the tasks involved logging into the system, requesting new equipment, and extending a loan request. On the other hand, the CECAS CORE staff was asked to perform the following tasks: (i) log in to the system, (ii) approve a loan

request, (iii) approve a loan extension request, and (iv) close a loan request. The completion time for each task per user was recorded. The users were encouraged to think aloud while performing the tasks. After completing the tasks, users were requested to provide further feedback on the overall interface and functions.

9.2. System Refinement

During the user testing, users provided feedback, which was used to refine the system. As an example, one of the menus was titled *Tasks.* The menu contained three sub-menus: Equipment loan request, Loan extension request, and Request history. Some users commented during testing that the title was confusing and vague (Figure 9.2). Based on the purpose of the menu, it was suggested that the title should be changed to *Requests.* The system was refined based on this feedback. A few of the other feedback is presented in Appendix C.

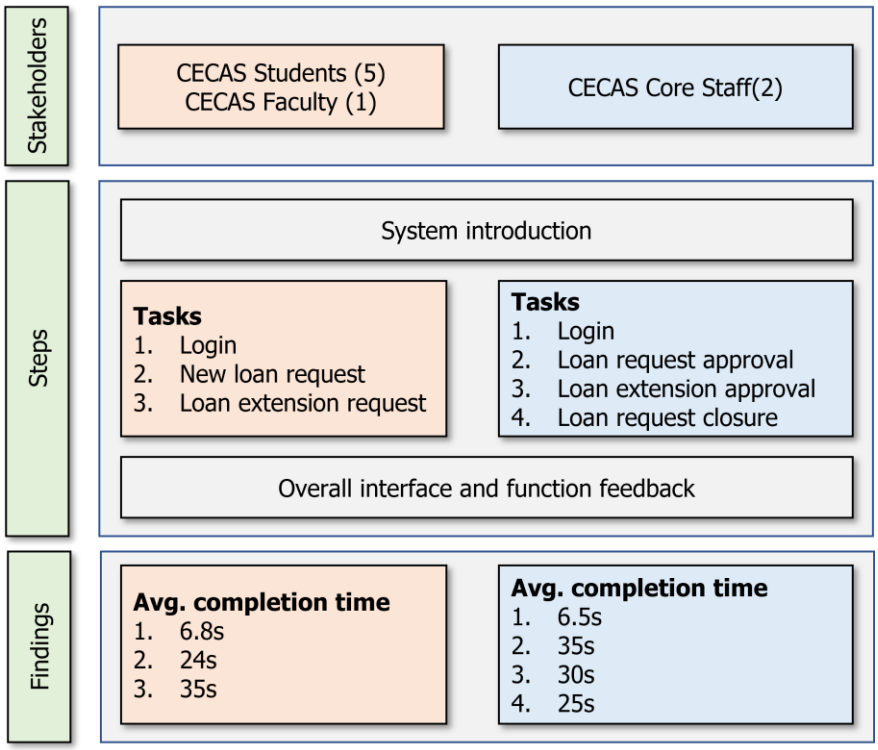


Figure 9.1. Loaner system testing procedure

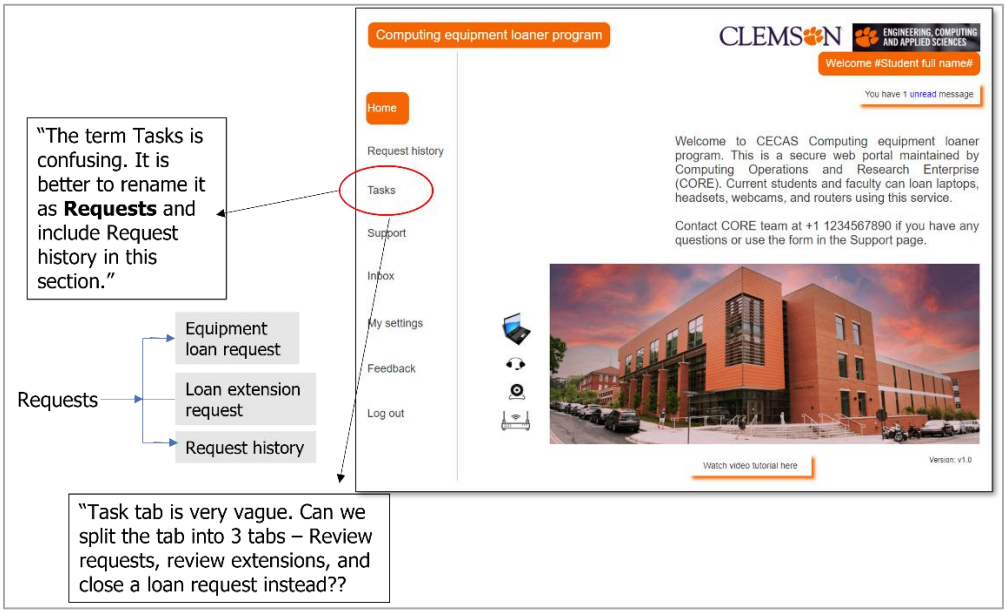


Figure 9.2. User feedback on a menu title

10. Final Design

The design went through several iterations based on all the users' feedback. In this section, we present screenshots of the final design of the user interface. The fully developed user interface can be accessed via https://wrqcnu.axshare.com. Figure 10.1 illustrates the first page is the Clemson CECAS home page, where we propose to add a new tab named *Services*, which can lead all the users to the equipment loaner system web page. This feature addresses the primary needs: "The system is easy to access," The system creates awareness about the loaning service," and "The system integrates with existing loaning systems within the university."

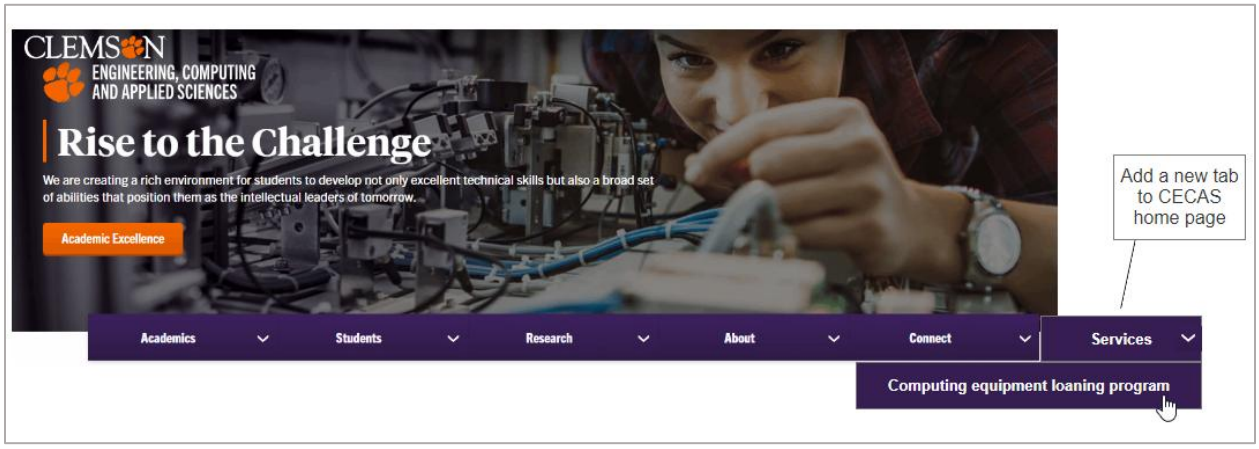


Figure 10.1. CECAS home page with an additional services tab

Figure 10.2 illustrates the multi-login page, which provides two interfaces: one for the student and faculty and the other for CORE staff. This page also includes information about the system description and a hyperlink to the main CCIT support page.

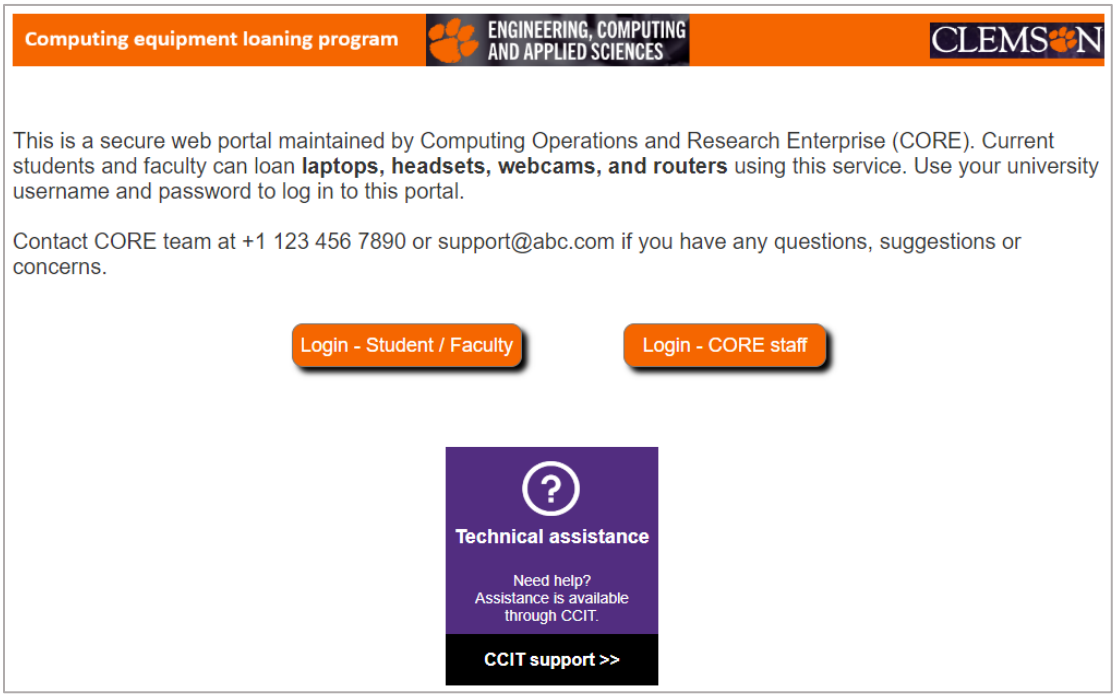


Figure 10.2. Multi-login page for two types of user profiles

10.1. Student / Faculty Interface

The Student/Faculty login page and the Terms and Conditions page are illustrated in Figure 10.3. The interface will proceed to the next page only after the user reads and agrees to the conditions.

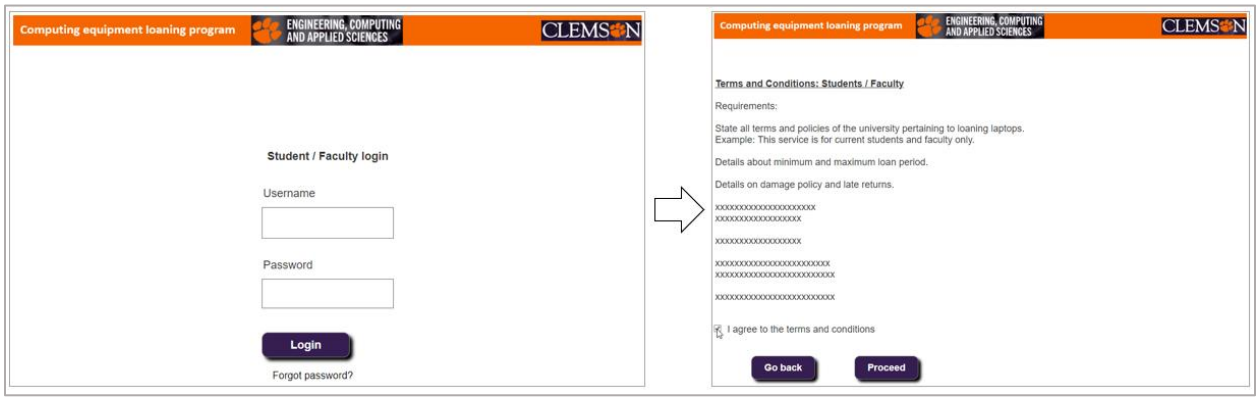


Figure 10.3. Student/Faculty login and Terms and Conditions page

The Student/Faculty Home page shown in Figure 10.4 consists of all the buttons aligned to the left of the page. A brief description of the system, the types of equipment that can be loaned, and contact details of the CORE team are provided. A dashboard is made available at the top right-hand corner, which summarizes the number of unread messages and the loan status of the user. The request equipment page is illustrated in Figure 10.5, where the four types of equipment and the up-to-date stock details are displayed. This adheres to the primary need "The system provides information about available equipment."

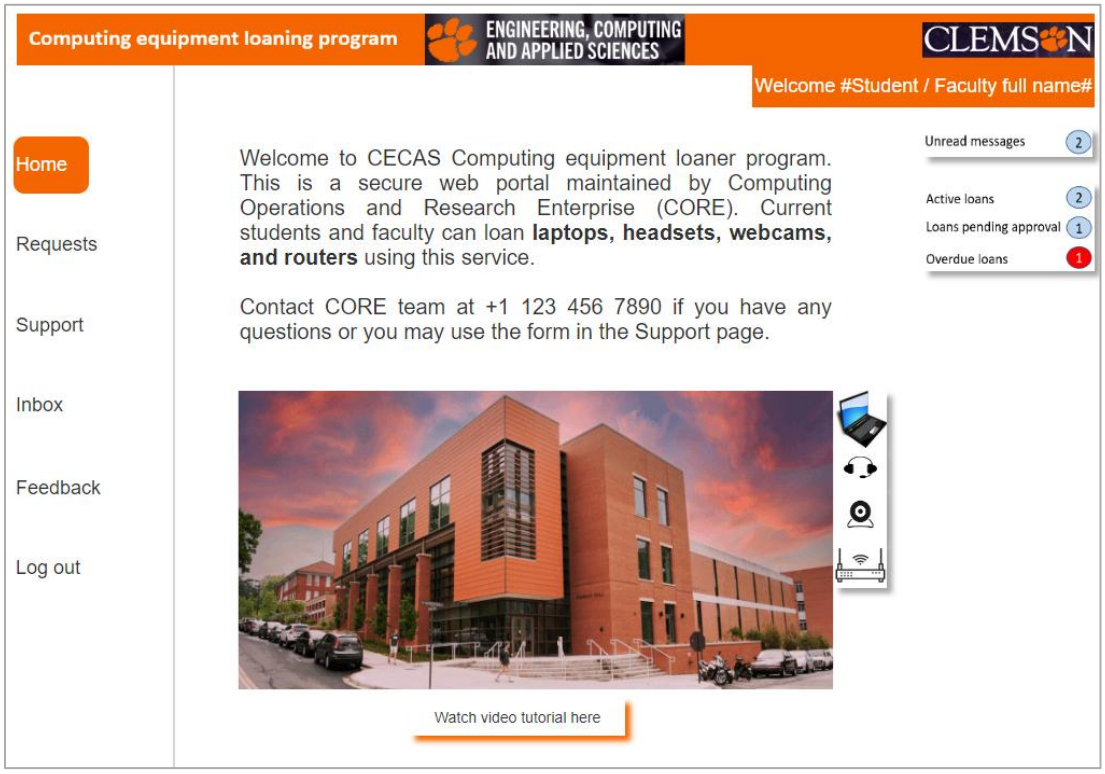


Figure 10.4. Student/Faculty home page

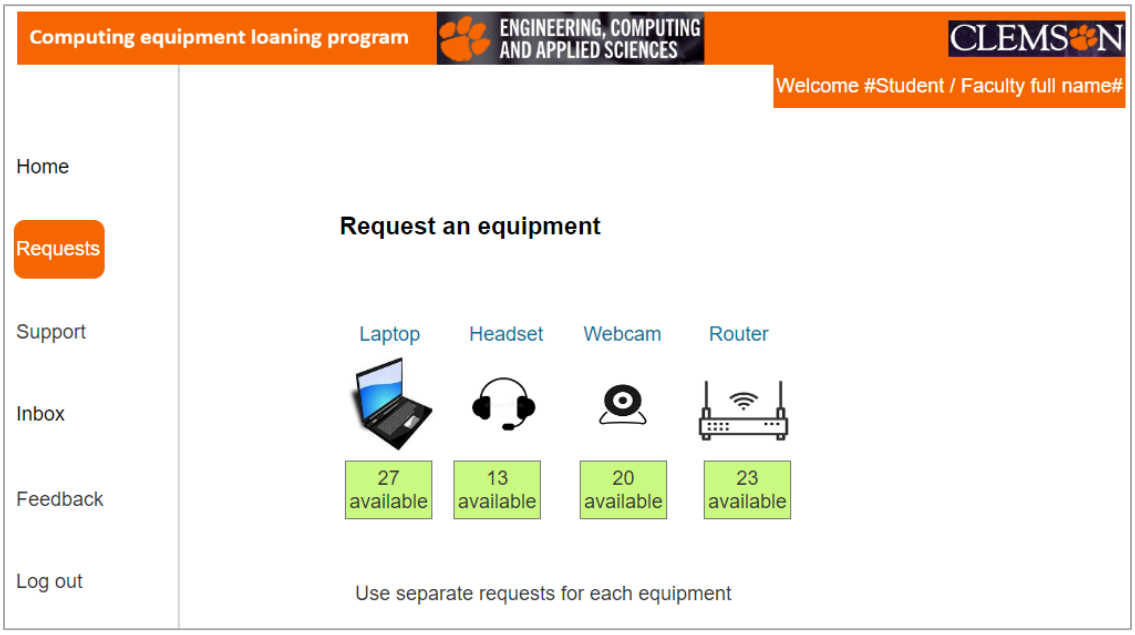


Figure 10.5. Request equipment home page

The request page for a laptop is illustrated in Figure 10.6. This page allows the user to provide specific software and hardware requests (this addresses a primary need). The user can view the equipment's stock availability and request accessories like a sleeve or a mouse. The reason for the request is a mandatory field. The default loaning period is set as two weeks from the request approval date. A clear message will be displayed with adequate information about the successful submission of the user's laptop request (See Figure 10.7).

The equipment extension page is illustrated in Figure 10.8. The user can select the existing request numbers and choose the extension period in weeks. This tab addresses the primary need "The system enables users to extend their loaning period." A special approval letter may be required to be uploaded for users requesting an extension of four weeks or more. A confirmation message similar to Figure 10.7 will be displayed after hitting the submit button. A support page is provided that allows users to communicate with the CORE staff about issues faced during the loan period or for any other general concerns about the service. A snapshot of the interface is illustrated in Figure 10.9.

A secure messages inbox, illustrated in Figure 10.10, is provided for users to track their requests and/or to perform actions requested by the CORE staff. A notification will also be sent to the user’s Gmail inbox (similar to the Clemson Redfern interface). This feature serves to bolster communication between users and staff. This feature notifies users about the stock availability, pick up, and drop off dates of the equipment requested.

A feedback page allows users to provide feedback about the equipment or service if they still need to complete this step after the request closure process. The feedback lets CORE staff derive valuable analytics that helps them make calculated decisions. See Figure 10.11.

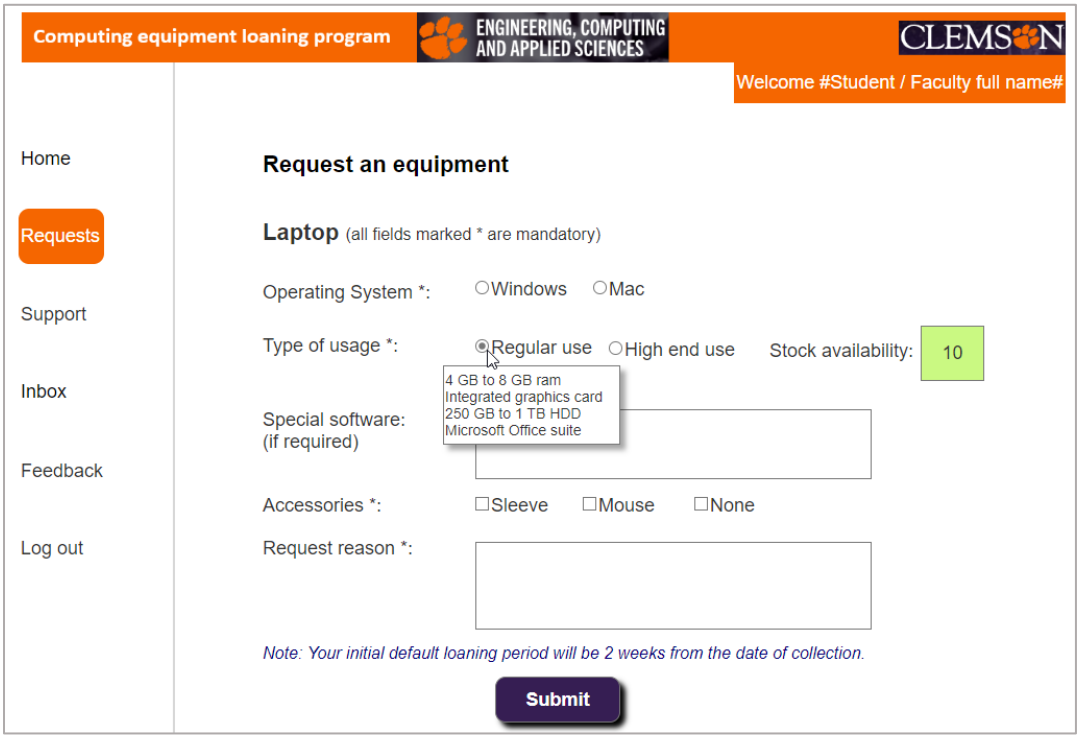


Figure 10.6. Laptop request page

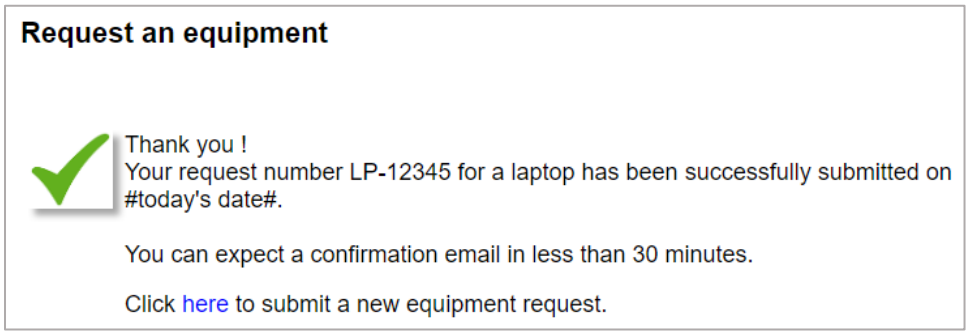


Figure 10.7. Confirmation message

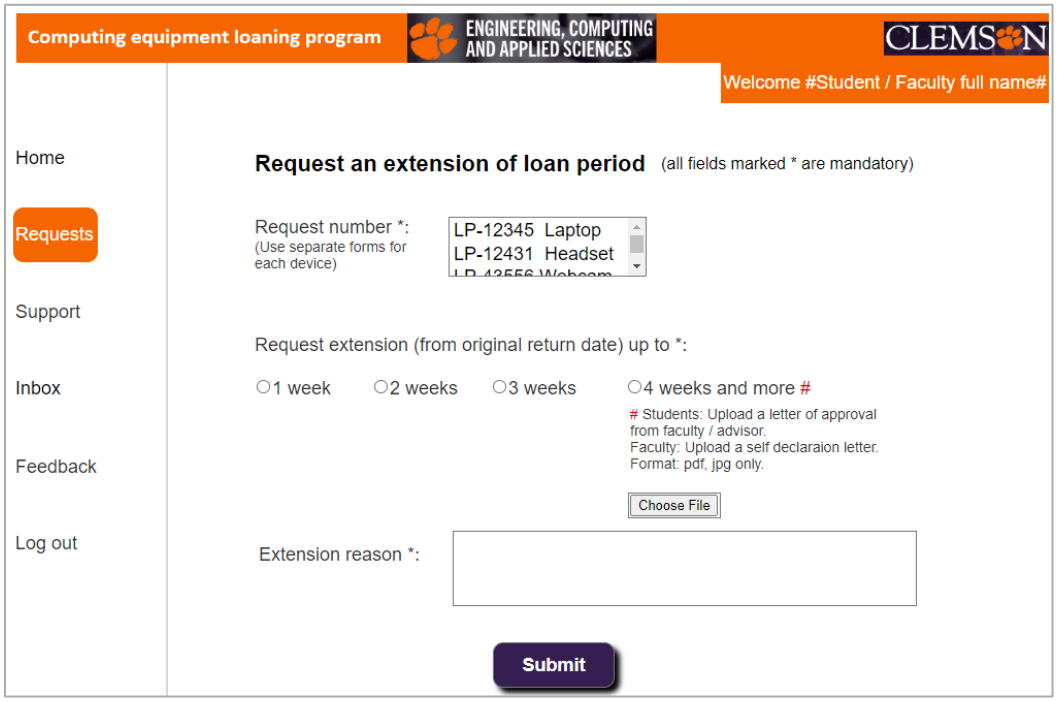


Figure 10.8. Interface for requesting an extension of equipment

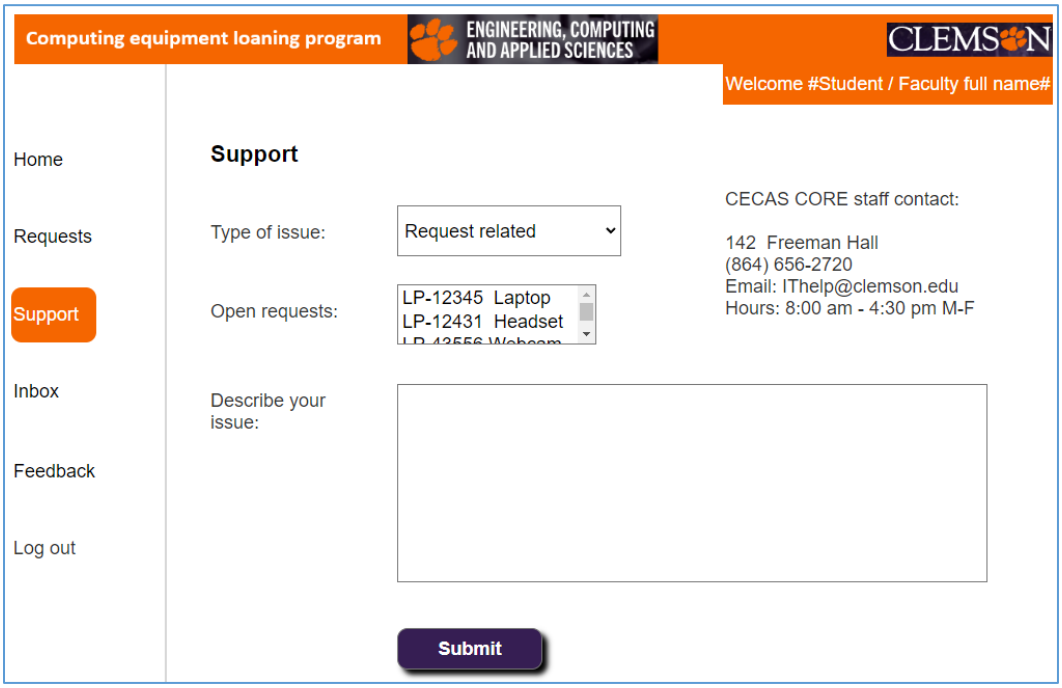


Figure 10.9. Support page

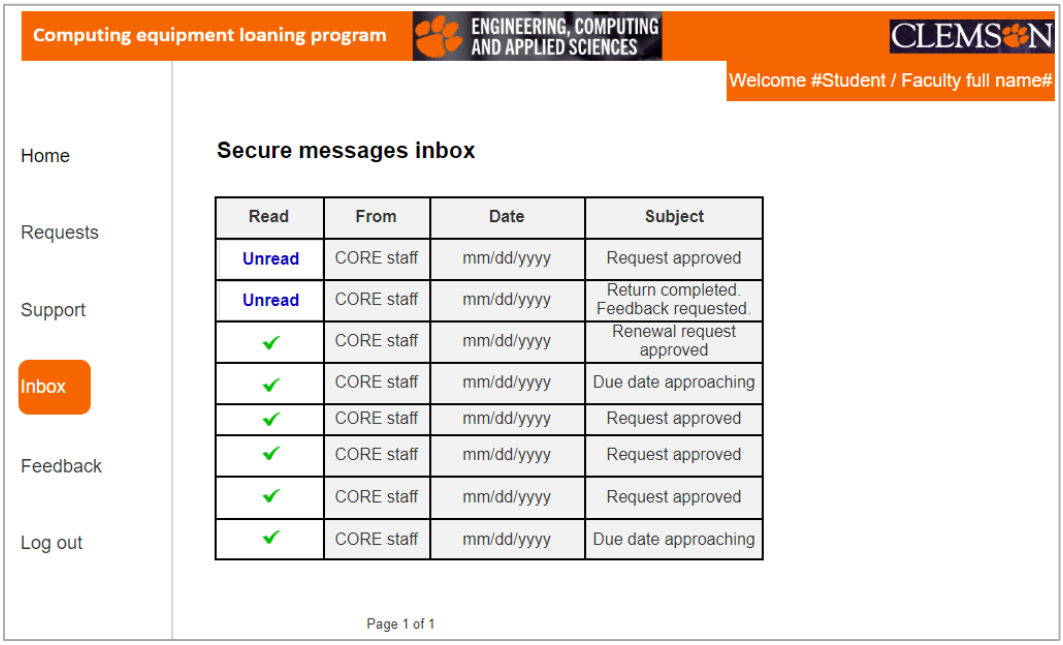


Figure 10.10. Secure messages inbox

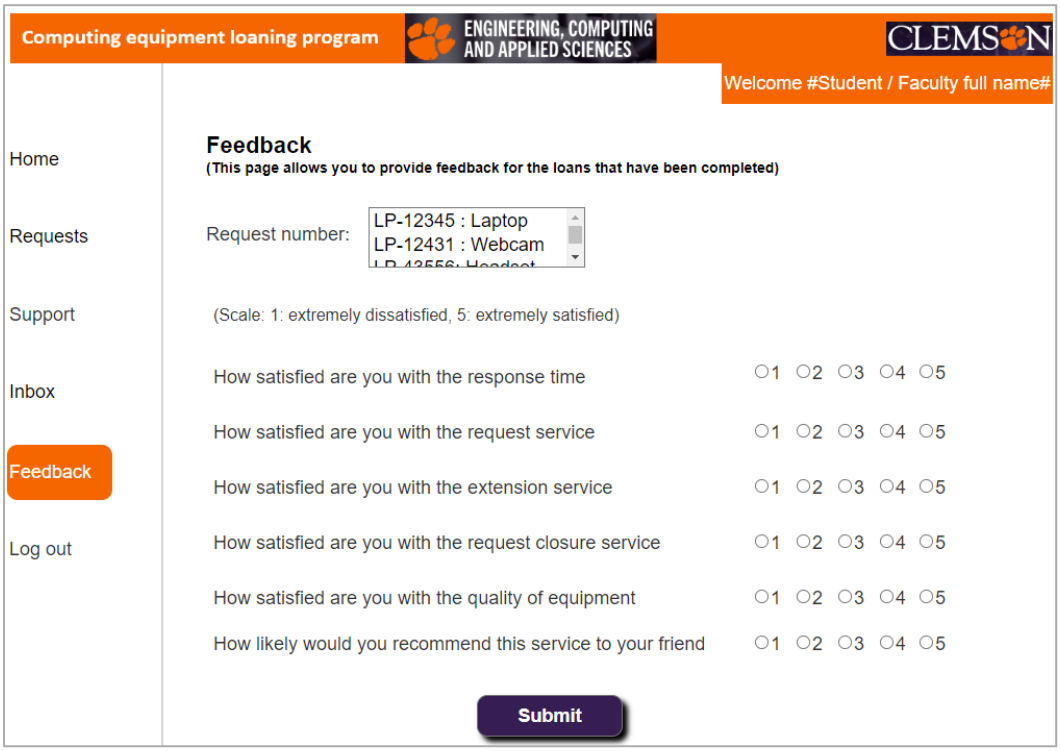


Figure 10.11. Feedback page

10.2. CORE Staff Interface

The CORE staff has a similar login page. The home page in Figure 10.12 contains multiple dashboards that provide a clear picture of the overall loan status and stock of equipment. All the user-specific action buttons are provided on the left side.

To process requests received, a CORE staff member in charge of approving/rejecting the request can proceed to the "New requests" tab (see Figure 10.13). Here, the staff can review the request details and can either approve/reject based on their discretion. This functionality helps reduce the response time between users and staff drastically. The renewal requests and request closure approvals have similar interfaces and action buttons. This function addresses the primary need "The system reduces waiting time for staff and users."

The inventory page shown in Figure 10.14 allows staff members to have a holistic view of the inventory and understand the status of each piece of equipment. There is a provision to update inventory by manually keying in the equipment details or barcode scanning. This feature addresses the primary need "The system keeps track of equipment inventory and requests." The analytics page illustrated in Figure 10.15 provides informative dashboards and graphs containing data about equipment, warranty period, demand, loan period, user feedback over time, etc.

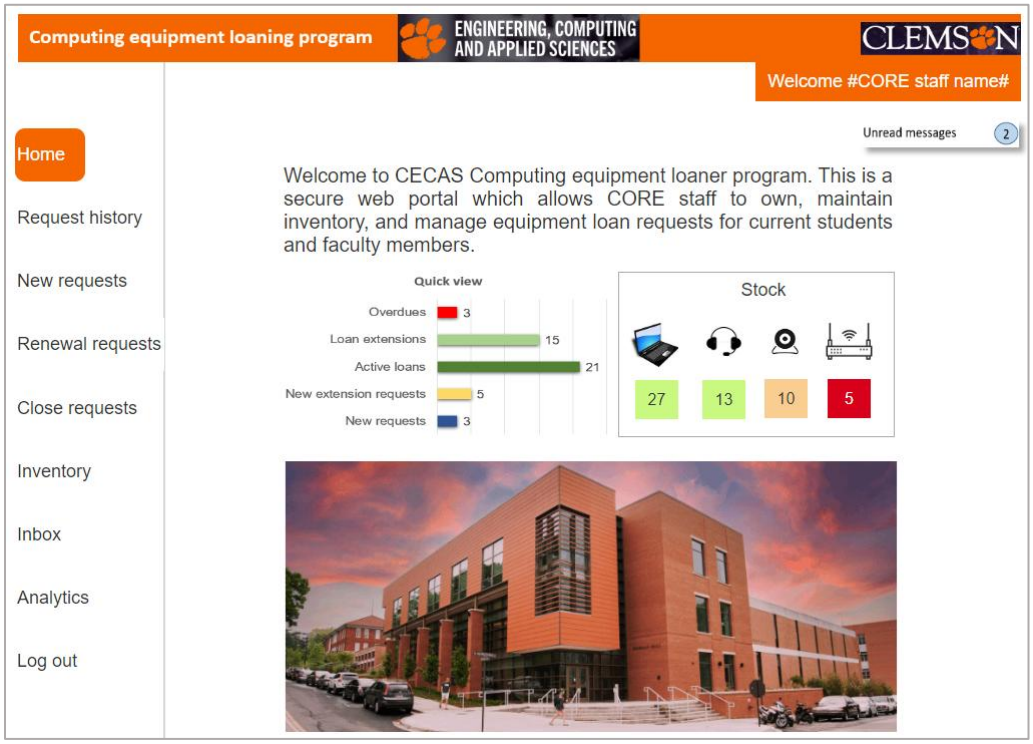


Figure 10.12. CORE Staff home page

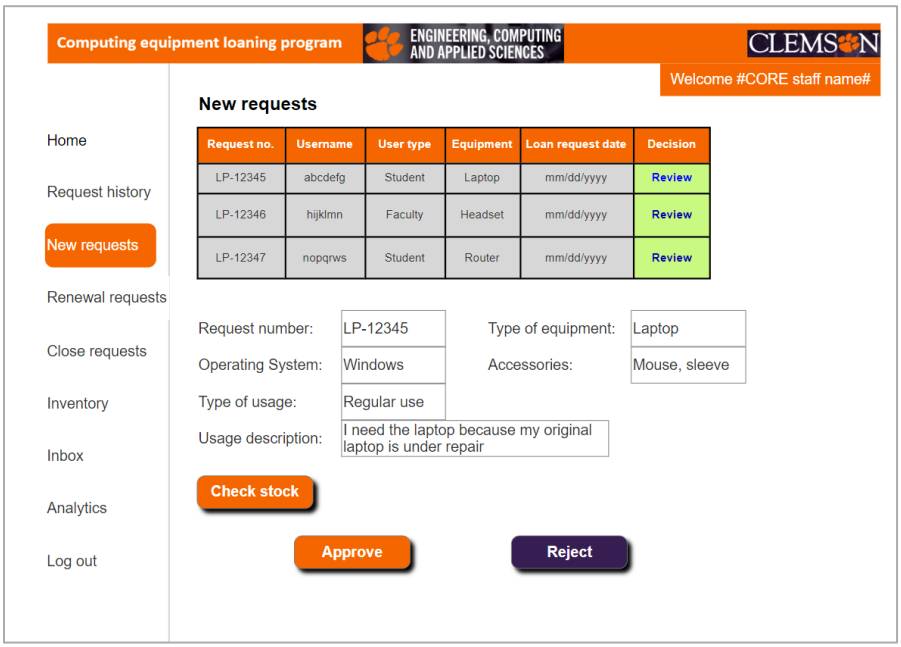


Figure 10.13. New Requests

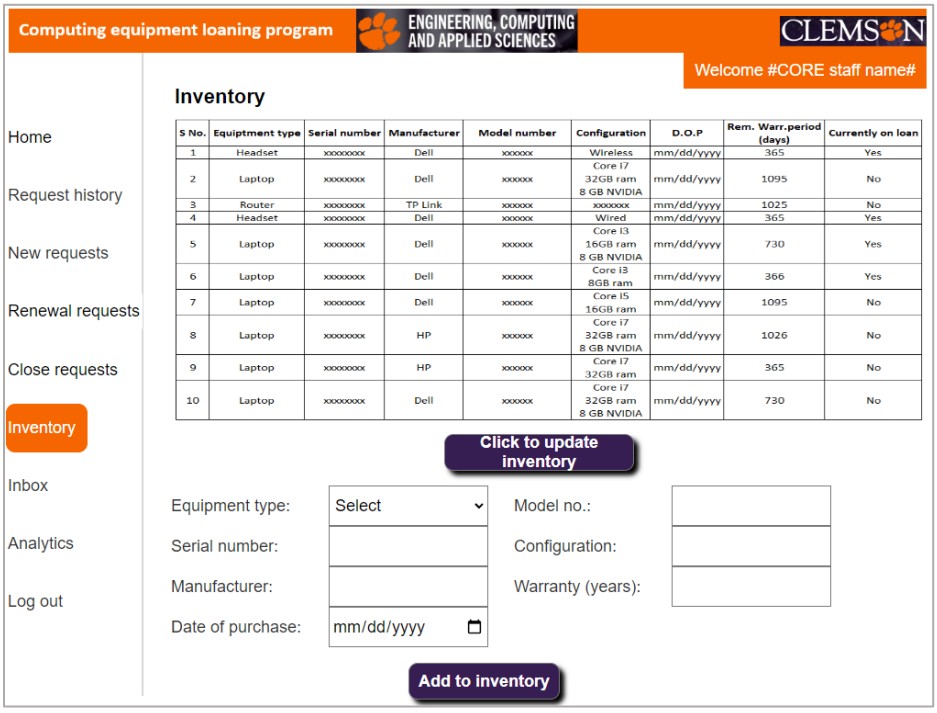


Figure 10.14. Inventory page:

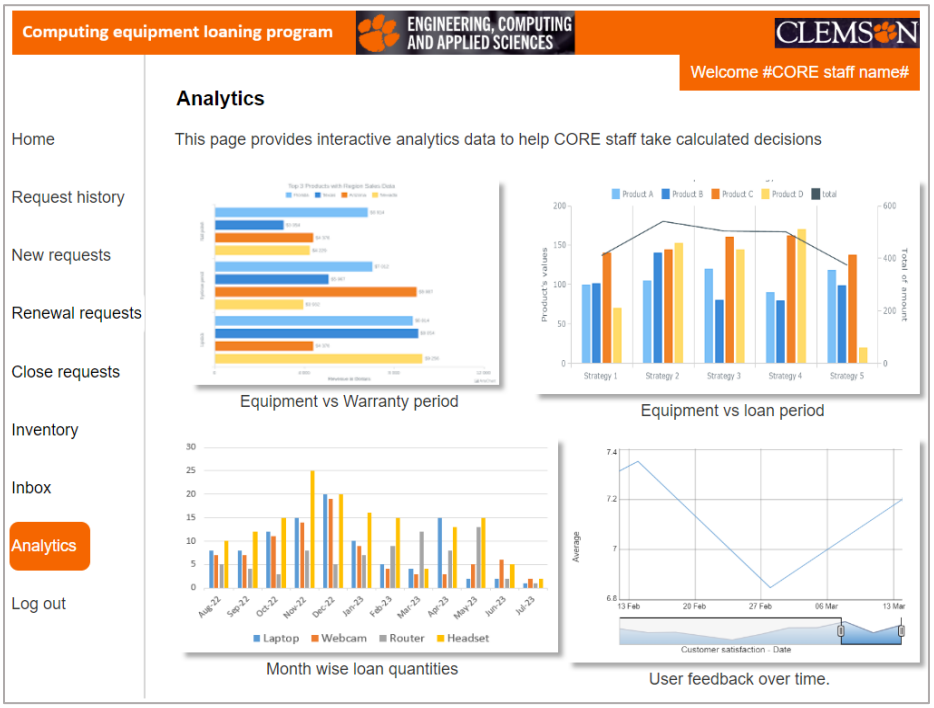


Figure 10.15. Analytics page

11. Performance Evaluation

After performing several iterations of the interface based on user feedback, we developed a final design concept. The next step was to evaluate the design against the target specifications. The stakeholders, which included five users and two CORE staff members, were requested to test the final user interface based on each target specification value. We recorded the task completion times of each user and calculated the average values. Table 11.1 illustrates the tested results against the ideal values that the team had confirmed initially based on competitive benchmarking. It was noted from the evaluation that some tasks, such as the average time to find information about available equipment, the average time to approve a loan request, etc., took less time than idealized. The optimized ideal values of nine technical specifications are emboldened in table 11.2. This exercise proves the effectiveness of the new user interface and how it could outperform the competition.

Table 11.1: Performance Evaluation with tested results.

Metric Nos.	Need Nos.	Metric	Imp.	Units	Marginal Value	Ideal Value	Tested results
1	1,6	Average time taken to find information about available equipment by 5 users	4,1	sec	<120	<60	8
2	2	Average time to complete a loan request by 5 users	1	sec	<300	<120	24
3	2	Average time to approve a loan request by 2 staff members	1	sec	<60	<50	35
4	3	Average time to complete loan extension request by 5 users	2	sec	<60	<50	35
5	4	Maximum time to log in to system using 3 different	4	sec	<10	<8	7

		devices (Desktop, Mobile, Tablet)					
6	5	Average time to complete 3 tasks by 7 users	5	sec	<240	<180	69
7	5	Average error rate in completing 3 tasks by 7 users	5	%	<5	0	0
8	5	Average completion rate of 3 tasks by 7 users	5	%	100	100	100
9	6	Average time to select software specification by 5 users	1	sec	<90	<60	23
10	6	Average time to select hardware specification by 5 users	1	sec	<90	<60	23
11	7	Creates awareness about the loaning service	1	Subj.	Yes	Yes	Yes
12	8	System integrates with the existing loaning systems within the university	1	Binary	Yes	Yes	Yes
13	9	Average time to access the equipment inventory by 3 staff members	3	sec	<480	<180	33
14	9	Average time to access the list of requests by 3 staff members	3	sec	<480	<180	40
15	10	Compliance to VPN / Information protection protocol	2	Binary	Yes	Yes	Yes
16	10,11	Frequency of sending reminders during loaning period	2,4	times/ week	>1	>2	>2
17	11	Notifications delivery rate for equipment pickup date	4	%	100	100	100
18	11	Notification delivery rate for equipment drop-off date	4	%	100	100	100
19	12	Provides security against theft and unauthorized usage	4	Subj	Yes	Yes	Yes
20	13	Notification delivery rate for equipment request	4	%	100	100	100
21		Development cost		US $	<9000	<7000	6675
22		Maintenance cost per month		US $	<500	<300	300

23	4,5	Compliance with ADA guidelines	5	Binary	Yes	Yes	Yes

Table 11.2: Updated target specification table based on performance evaluations (updated ideal values are emboldened)

Metric Nos.	Need Nos.	Metric	Imp.	Units	Marginal Value	Ideal Value
1	1,6	Average time taken to find information about available equipment by 5 users	4,1	sec	<120	**<10**
2	2	Average time to complete a loan request by 5 users	1	sec	<300	**<30**
3	2	Average time to approve a loan request by 5 users	1	sec	<60	**<40**
4	3	Average time to complete loan extension request by 5 users	2	sec	<60	**<40**
5	4	Maximum time to log in to system using 3 different devices (Desktop, Mobile, Tablet)	4	sec	<10	<8
6	5	Average time to complete 3 tasks by 7 users	5	sec	<240	**<80**
7	5	Average error rate in completing 3 tasks by 7 users	5	%	<5	0
8	5	Average completion rate of 3 tasks by 7 users	5	%	100	100
9	6	Average time to select software specification by 5 users	1	sec	<90	**<30**
10	6	Average time to select hardware specification by 5 users	1	sec	<90	**<30**
11	7	Creates awareness about the loaning service	1	Subj.	Yes	Yes
12	8	System integrates with the existing loaning systems within the university	1	Binary	Yes	Yes
13	9	Average time to access the equipment inventory by 3 staff members	3	sec	<480	**<40**

14	9	Average time to access the list of requests by 3 staff members	3	sec	<480	**<50**
15	10	Compliance to VPN / Information protection protocol	2	Binary	Yes	Yes
16	10,11	Frequency of sending reminders during the loaning period	2,4	times/week	>1	>2
17	11	Notifications delivery rate for equipment pickup date	4	%	100	100
18	11	Notification delivery rate for equipment drop-off date	4	%	100	100
19	12	Provides security against theft and unauthorized usage	4	Subj	Yes	Yes
20	13	Notification delivery rate for equipment request	4	%	100	100
21		Development cost		US $	<9000	<7000
22		Maintenance cost per month		US $	<300	<300
23	4,4	Compliance with ADA guidelines	5	Binary	Yes	Yes

12. Cost Analysis for the Final Concept

The cost of developing the final concept, adapted from Burak's (2021) guidelines, is presented in Table 12.1. The different services include the following:

i. Front-end development: Focuses on the functionality of the system.

ii. Back-end development: Focuses on the server-side of the system

iii. UI/UX: Focuses on system interface, navigation, and overall aesthetics to ensure a positive experience for users when they use the system.

iv. Testing/Quality assurance: User testing of the system and ensuring system quality.

v. Project management: Overall management of the entire project.

vi. Training: Training of system users to use the system.

vii. Overhead: Miscellaneous services.

Table 12.1: Final concept cost analysis.

#	Services	Cost/hour	Hours		Cost	
			Min	Max	Min	Max
1	Front-end development	$30	40	45	$1,200	$1,350
2	Back-end development	$35	40	45	$1,400	$1,575
3	UI/UX design	$25	25	30	$625	$750
4	Testing/Quality assurance	$25	30	35	$750	$875
5	Project management	$35	40	45	$1,400	$1,575
6	Training	$20	10	15	$200	$300
7	Overheads	$10	20	25	$200	$250
	Total		**205**	**240**	**$5,775**	**$6,675**

Timeline: 1–2 weeks if 1 front-end developer, 1 back-end developer, and 1 quality assurance specialized are involved

The estimated minimum and maximum number of hours required to complete each aspect of the development process are presented, as well as the respective cost per hour. Thus, the minimum and maximum costs for each service is calculated by multiplying the corresponding hours and cost per hour.

13. Final Recommendations

Considering all the concept variants, we recommend the stakeholders to implement our final design as it addresses all the primary needs identified and has been run through several relatively successful usability tests. There are some recommendations and limitations to the system that need to be considered for the overall success of the system. We have assumed that the users have access to a laptop/computer when submitting a request for a loaner laptop, but in case their laptop is broken and they do not have access to one to put in a request, the current process of requesting a loaner laptop should still be kept active. In such a scenario, the CORE staff would

have to manually log in a request on the system to keep the inventory list up to date. A mobile or tablet-friendly system can also help resolve this problem.

The feedback received should be monitored closely to ensure the usability of the system. This system will thrive if continuous improvement strategies are used, and the feedback the users provide will be insightful and crucial in keeping the system user-friendly and useful in the long run.

14. Implementation Plan

The front-end interface prototype has been successfully developed, tested, and approved by the stakeholders. A final coding of the front- and back-end is required for the website to be operational and functional. The cost estimation has been done, and the project will be handed over to the CORE staff. The development team should be able to build and test the complete software with a group of users (the same stakeholders) before releasing it to a larger audience. Adequate support may be provided during the early days of software implementation to address glitches or bugs and to improve the system's robustness.

15. Summary and Conclusion

The project was aimed at developing a system that provides support in tracking equipment loaned to students/faculty, and that establishes an effective communication channel between users and the CORE staff members. The primary needs identified were successfully converted into design specifications and were incorporated into the design. The final design will make the equipment-requesting process more straightforward, and the system will be easily accessible.

Furthermore, the new system will significantly reduce the time for decision-making. This will provide students with a wholesome and positive educational experience at Clemson University.

References

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Ulrich, K. T., & Eppinger, S. D. (2016). Product design and development (6th ed.). McGraw-Hill Education.

Appendix

Appendix A: Personas

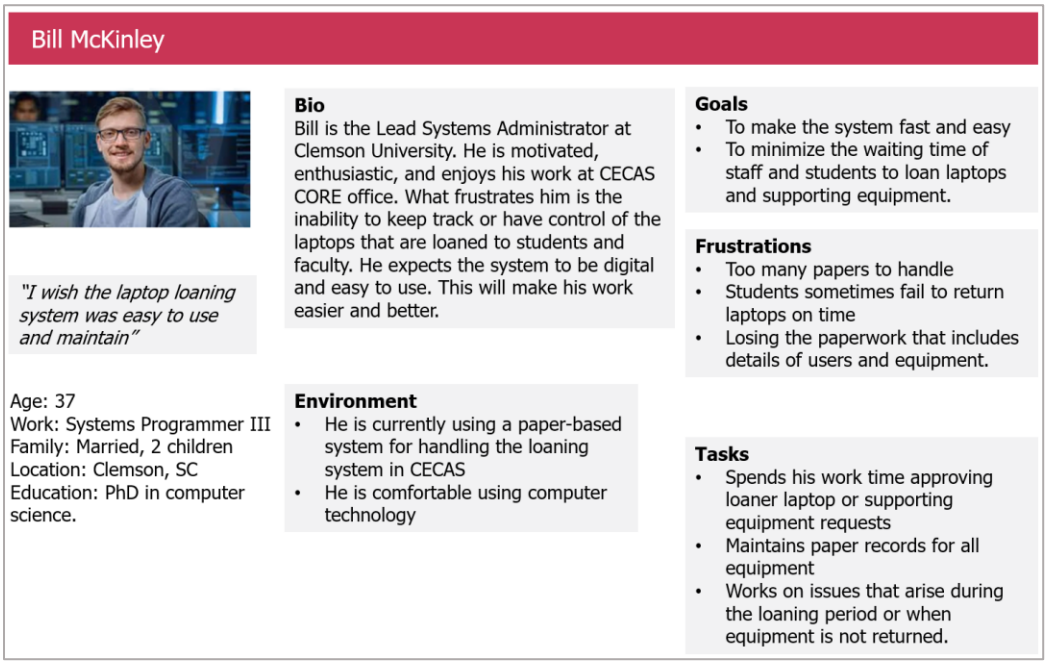

Figure 16.1. CORE staff persona

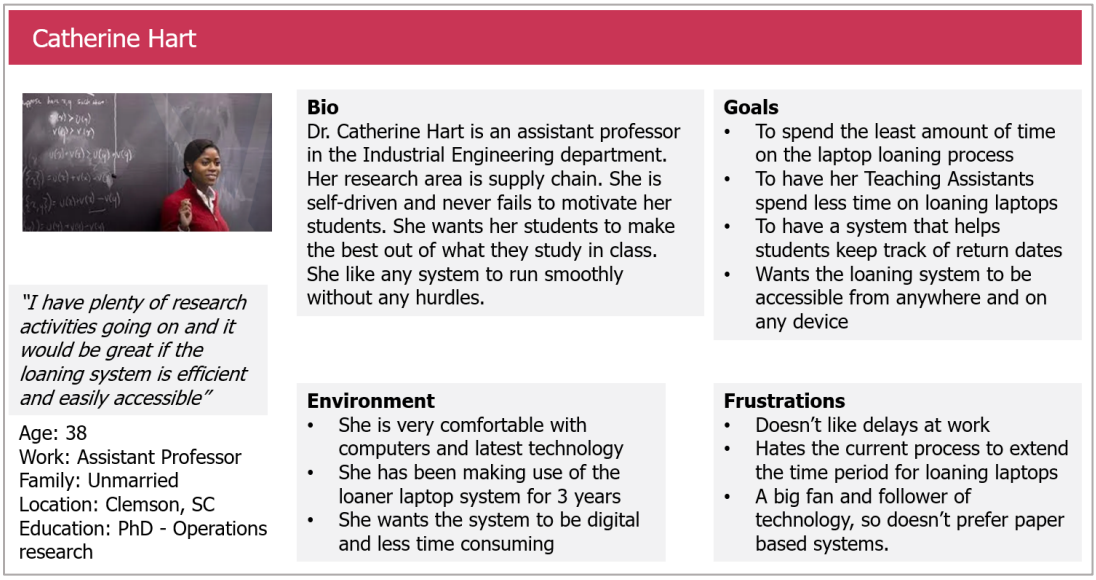

Figure 16.2. Faculty persona

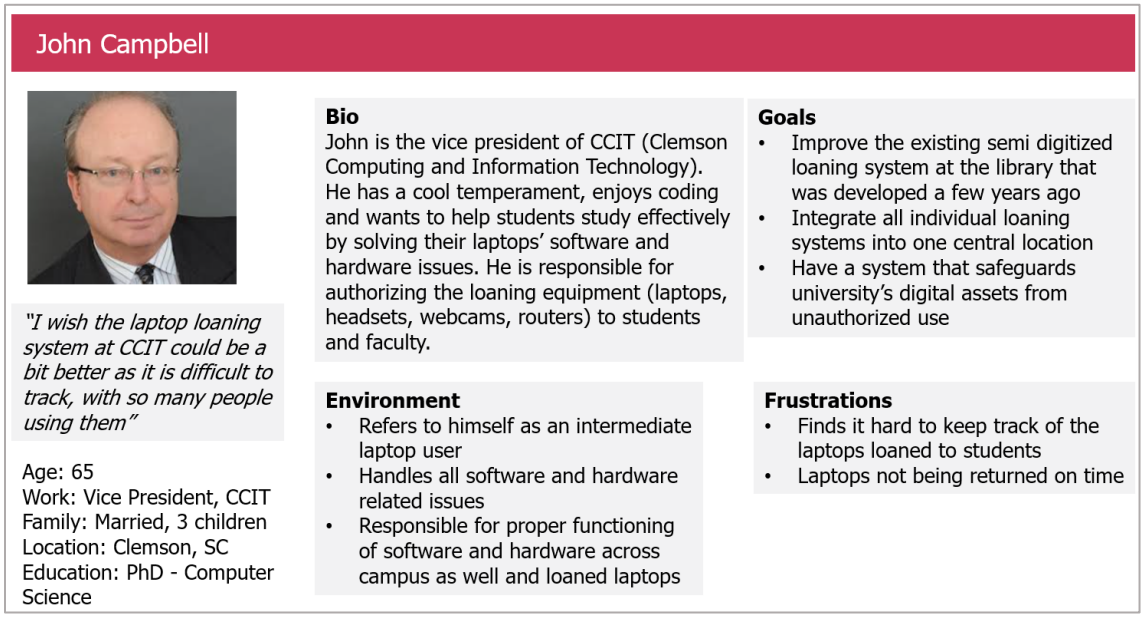

Figure 16.3. CCIT staff persona

Appendix B: Concept Variants

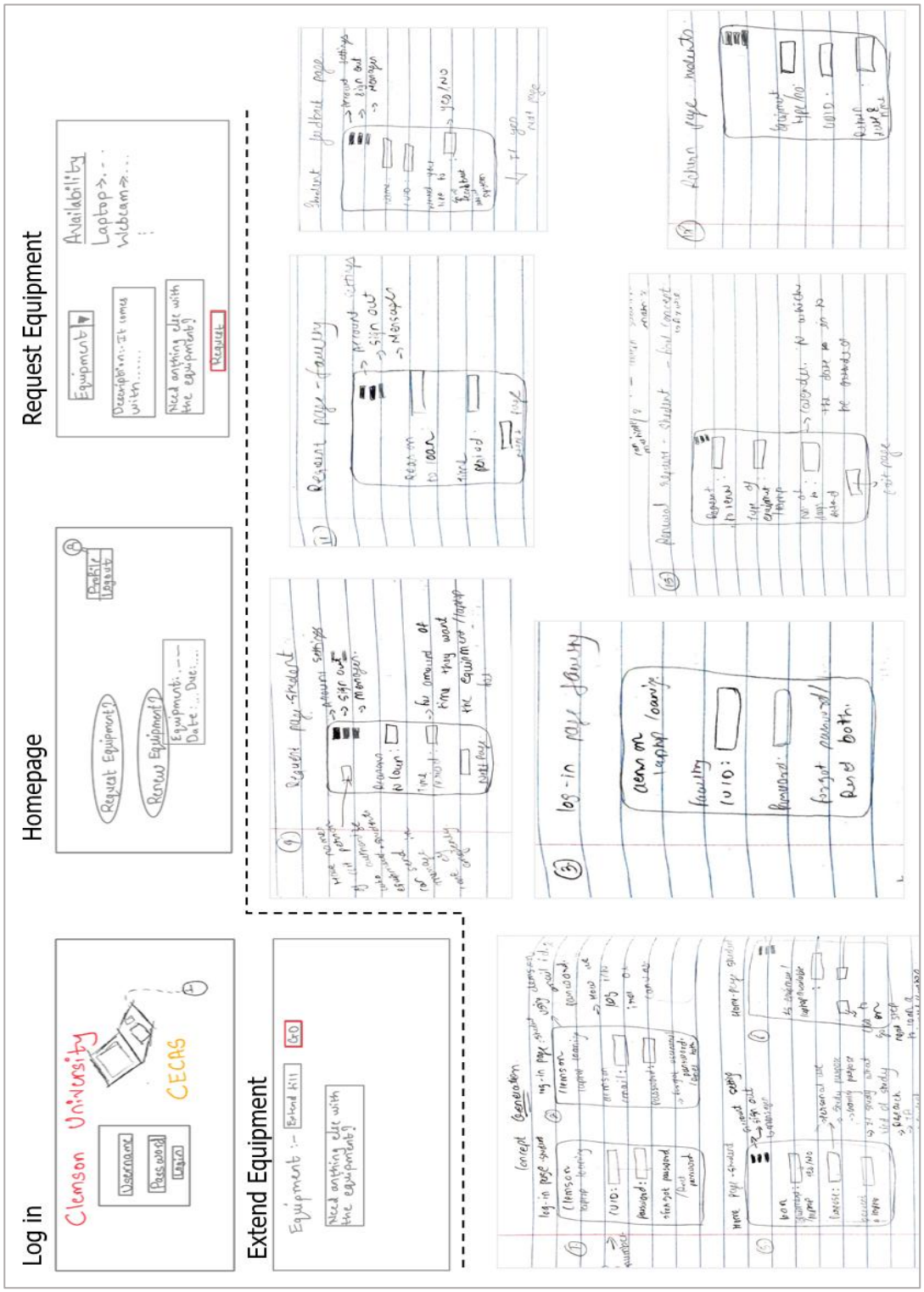

Figure 16.4. Concept variant 1 and 2

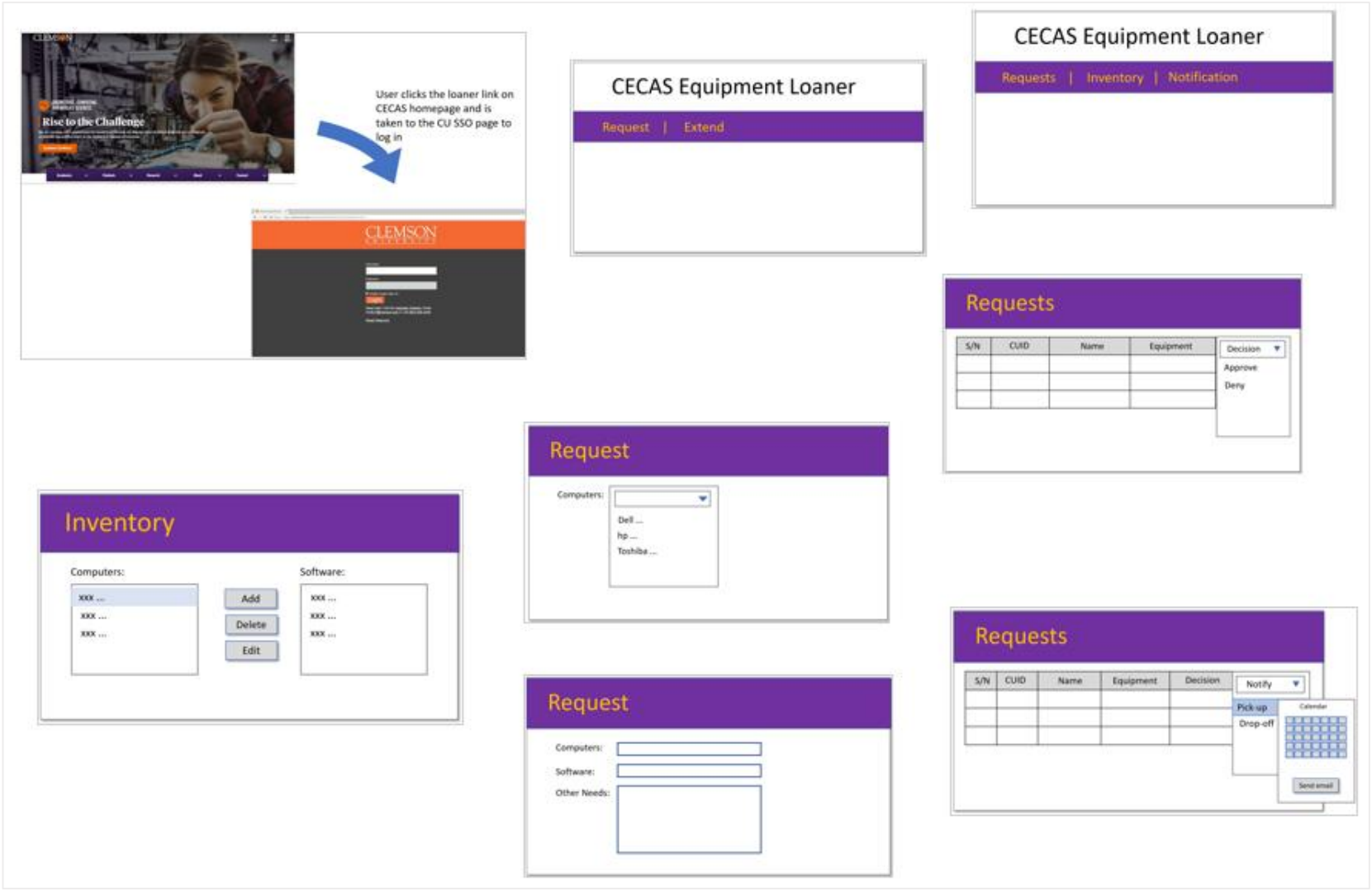

Figure 16.5. Concept variant 3

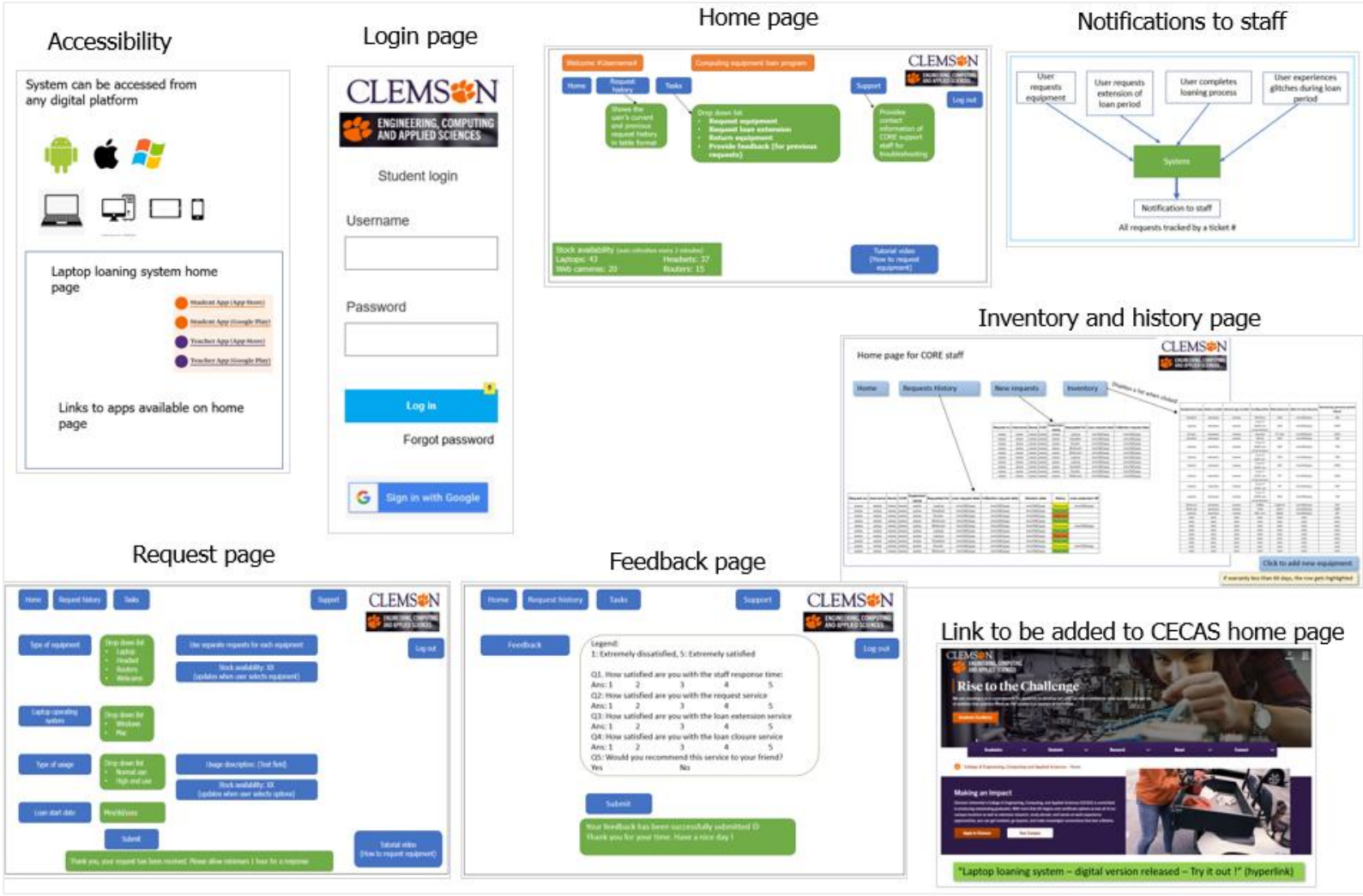

Figure 16.6. Concept variant 4

Appendix C: Prototype Testing - User Feedback

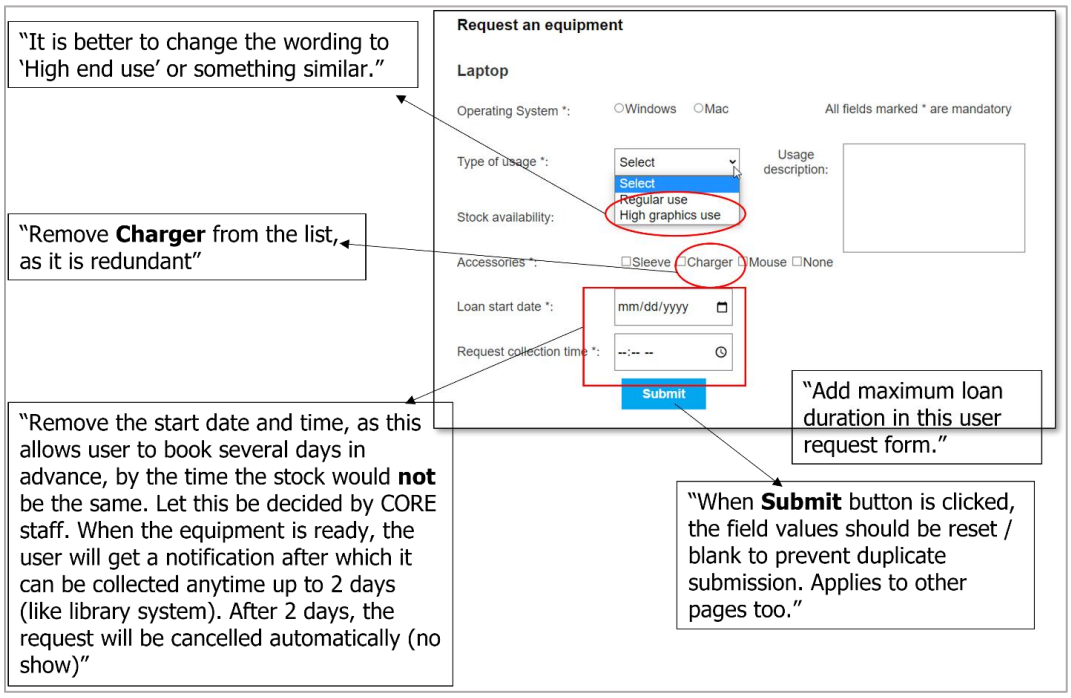

Figure 16.7. User feedback example 1

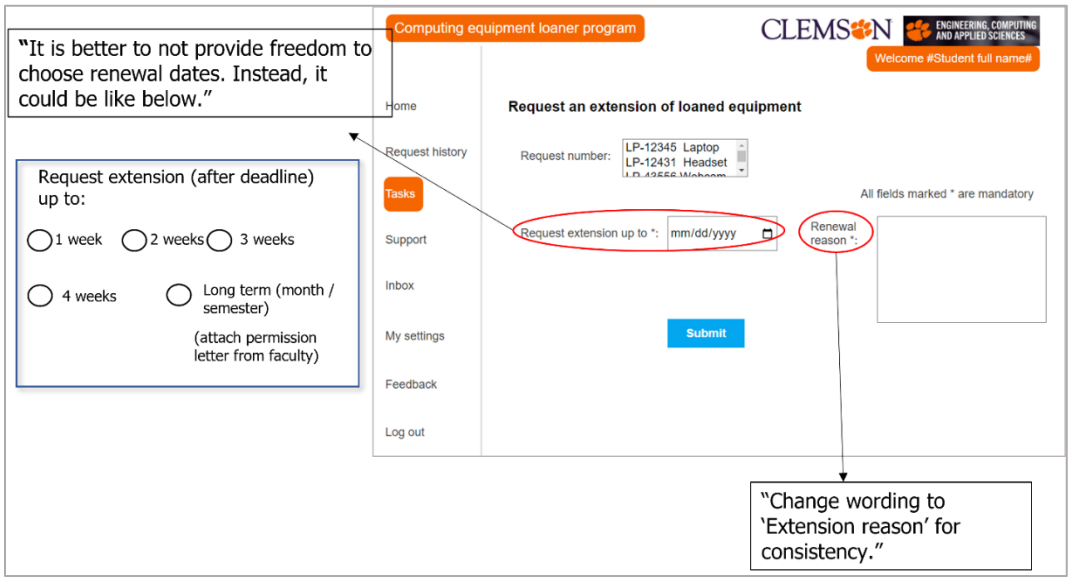

Figure 16.8. User feedback example 2

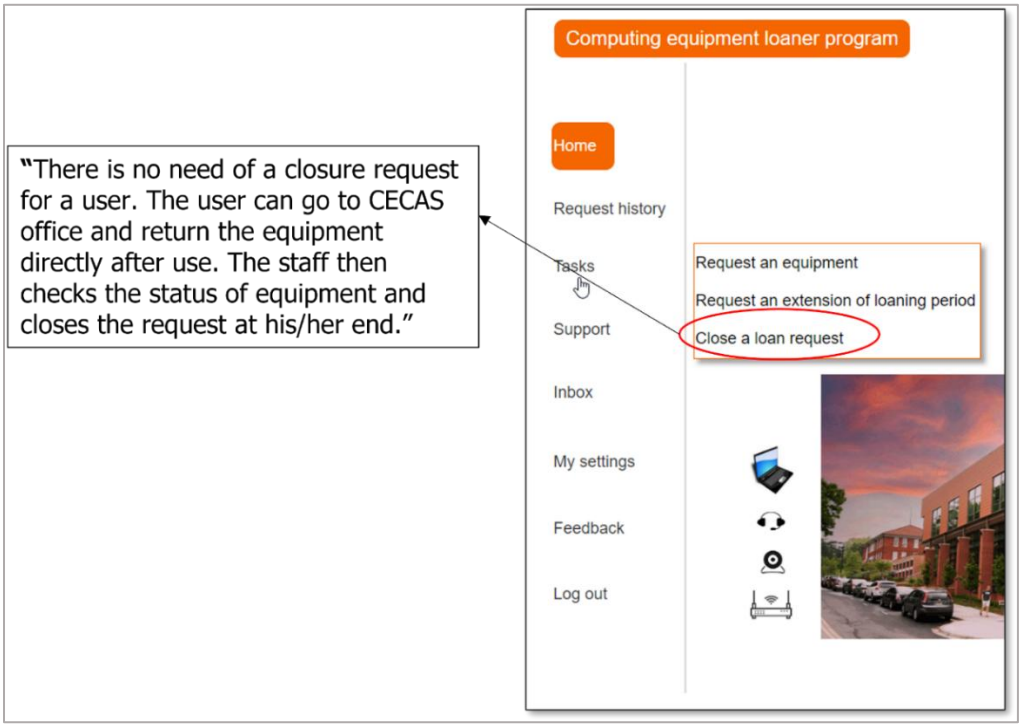

Figure 16.9. User feedback example 3

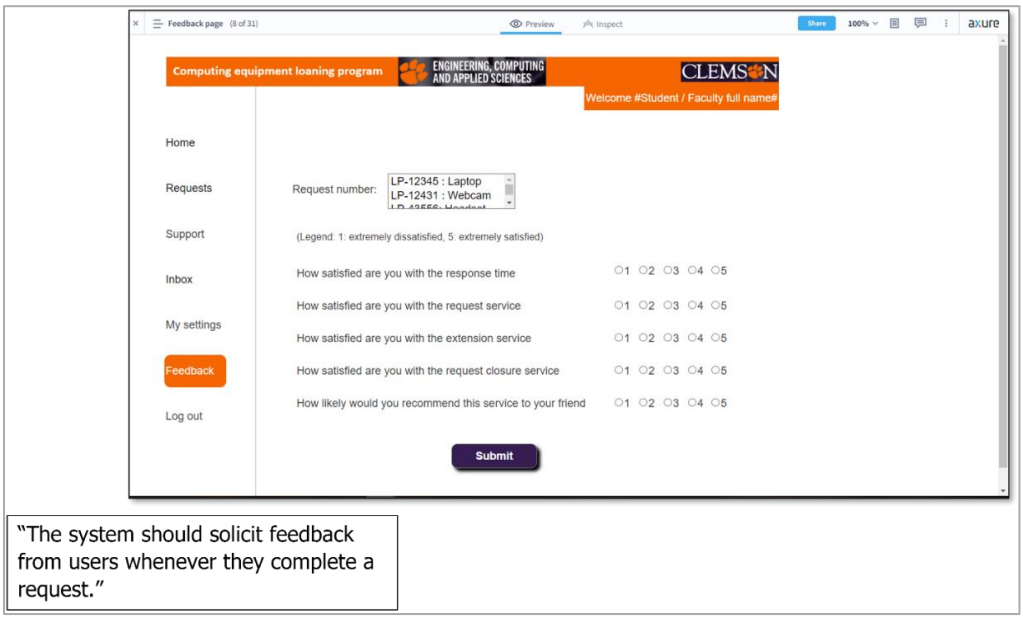

Figure 16.10. User feedback example 4

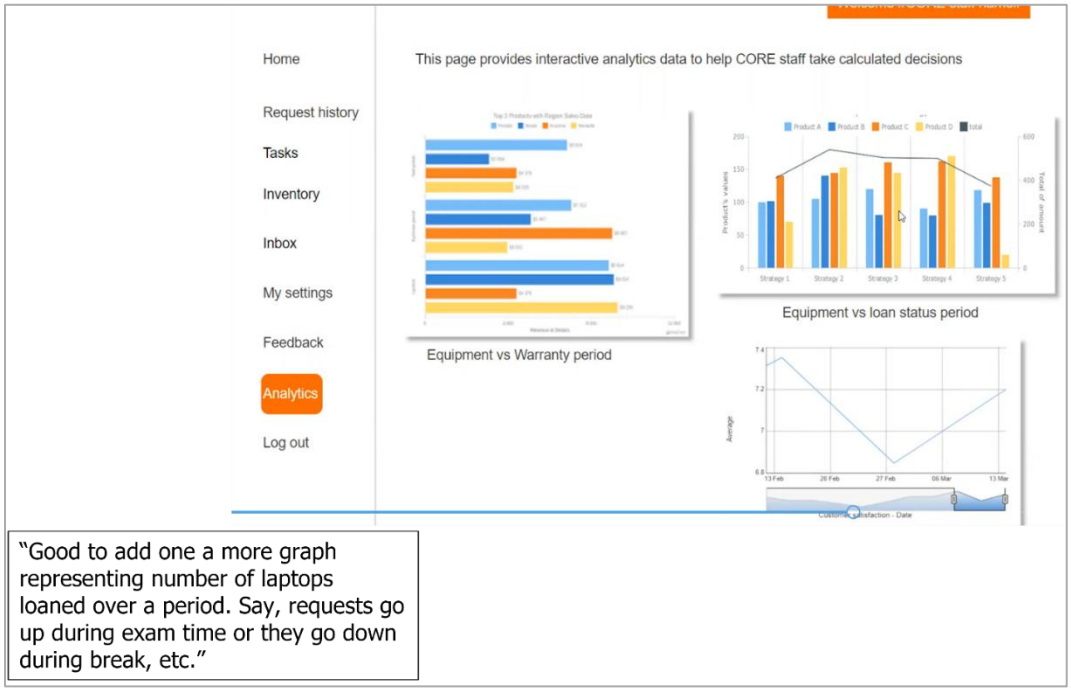

Figure 16.11. User feedback example 5