IPRO It takes a team! INTERPROFESSIONAL PROJECTS PROGRAM

IPRO 337

Zero Energy Lab
and
Designing the IPRO Team Collaboratory Space

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1. Executive Summary

IPRO 301/337 combines the ideas of two previously separated IPRO's: designing a collaboratory space for IPRO tracks and building a Zero Energy Lab. The two concepts are combined to complement each other, ultimately designing a Net Zero IPRO Collaboratory Facility. IPRO 337 researches many different ways to create a self efficient building that requires no more energy than it is capable of producing. The Zero Energy Lab team is sponsored by DOE/EPA Labs 21, KSA Lighting, and Lithonia Meccho Shade. The main project of this semester is to design and build a wind generator that would provide enough energy to charge the current battery bank that is already set up in the lab. Previous semesters have done extensive research on alternative energy and energy storage, and we wanted to research, design, and create something that would recharge the energy storage system set up by the previous IPRO's. We also very briefly looked into designing a lighting system to illuminate the Zero Energy Lab during non-daylight hours by looking into radiant paint for the walls. Essentially, the walls would be charged during the day and will emit a glow at night.

The Programming team's track is to design a new collaboratory space dedicated to the IPRO program. Currently the IPRO classes are held in E1, Hermann Hall, 3424 S. State and various other locations disbursed throughout the main campus. As of now, IPRO lacks the expression of its unique fingerprint among other academic programs at IIT. The current facilities provided for IPRO's students and faculty are very small in square footage, lacking numbers of classrooms, conference rooms, studios, and workshop spaces required to function efficiently. The goal of the Programming team is to develop a collaboratory space for its students and faculty with an open plan, allowing them to interact, mingle, and cooperate as a team. Supporting spaces such as labs, shops, gallery, and breakout space will accompany the innovative spaces. We have conducted student and faculty surveys, existing site surveys, an interview with IPRO director Thomas Jacobius, and from the gathered data developed a program for the new building. The desired square footage of the new building is 41,377 square feet, and the CTA building on the North side of the campus has been appointed as the most ideal to accommodate this condition.

In order to determine the suitability of the CTA building as a prospective collaborative IRPO space, the Building Feasibility team was charged with the goal of analyzing the building's current energy use and looking into what improvements would have to be made to the building for it to be as zero energy as possible. By collecting historical data and through the use of technologies such as thermal imaging, it was possible to create an energy model of the building using the energy simulation software eQuest. With this model, we could run simulations of what improvements could be made to the structure of the building in order to minimize the amount of energy it uses. Finally, by applying both the data gathered by the Programming team and the information on zero energy technology from the Zero Energy Lab team, we were able to create a plan for what technologies could be applied to the CTA building in order to make it as zero energy as possible.

2. Purposes and Objectives

As sustainability is becoming more predominant in our way of life today, new technologies and ways to apply these technologies are needed to provide us with the green resources we need. Through small steps that we can take to become more green, the earth can become a better place for everyone. It is this idea that drives this IPRO, and in particular, the Zero Energy Lab subgroup. The Zero Energy Lab is located at the top floor of Machinery Hall, and it is the location that we conduct all of our studies. That is the physical location in which we learn about new technologies and apply them to the space in order to evaluate their effectiveness.

The Zero Energy Lab subgroup's objective is to continue improving the space allocated to us. We would like this space to eventually house all IPRO courses and provide a functional, educational, and innovative space for studying. This semester we have studied wind energy in particular, and have worked out a way to utilize this energy and store it for later use. The wind turbine technology that we have studied will eventually be used on a larger scale to create a more efficient space in machinery Hall.

The goals we have set forth were to:

1. Research wind power technologies
2. Construct working small scale models to further study wind
3. Construct one full scale model of a working wind turbine based on previous model studies

Through the accomplishment of these objectives we have acquired the resources to further develop the space of Machinery Hall and pave a path of relevant information for future Zero Energy Labs to walk on.

One of the obstacles in the programming of the IPRO space is the inclusion of technologies researched by the Zero Energy Lab. It is the desire of the IPRO to apply the Zero Energy concepts to the CTA building as a presentation of what IPRO's are capable of accomplishing. However, before any such thing can be done the suitability of the technology for the CTA building must be studied. The Building Feasibility group's goal is not only to analyze the suitability of Zero Energy technologies on a tech by tech basis, but also to create an energy model capable of simulating the effects of any possible new technologies or building alterations that could be installed in the building. In order to accomplish this the CTA building is being studied in its present state. With an existing conditions energy model in place it will greatly aid the process of comparing the costs and benefits of any new technologies.

1. First the group will begin learning how to create an energy model in eQuest. The most pertinent information to gather from the software is what building properties it requires to run a simulation. To assist us in learning some of the less intuitive functions of the software our advisor, Nancy Hamill, has provided us with a contact from eQuest.
2. To begin gathering information about the CTA building we will either find or create drawings of the floor plans and elevations of the structure.
3. Once we have these drawings they will provide us with the dimensional data of the structure as well as the building materials and insulation. All of this information will be input into eQuest.
4. The light fixtures in the CTA building were upgraded recently so accurate lighting specifications are available. Using this information in tandem with the floor plans the power consumption per square foot for each of the zones in eQuest will be calculated and entered into the energy model.
5. The next major information to input into eQuest is the HVAC systems. This includes the type of heating/cooling equipment, what amount of power they draw, what their schedules of operation are, and what zone of effectiveness they have in the building.

6. Also, the facilities department on campus will provide us with a thermal imaging camera which we will use to study the shell of the building. With the thermal images we will find the areas of the building with the greatest heat leakage.

At this point there is still information to be input into the energy model, however, the most pertinent data will already be entered into eQuest and the model will be ready to create simulations. Now any technologies that are being studied or considered by the IPRO can be analyzed for feasibility in the CTA building. This includes running comparative simulations in eQuest to estimate the energy savings as well as researching the physical application of the technology to the building. For example, if a solar-thermal array was to be installed on the roof of the building then building codes, structural integrity of the roof, and stresses caused by the array would have to be considered. Using the findings of the simulations and research the IPRO will be able to make decisions regarding the application of Zero Energy technologies in a quick and efficient manner.

3. Organization and Approach

The Zero Energy Lab subgroup was focused on two main goals this semester: (1) design and construction of a working vertical axis wind turbine and (2) accumulation of the previous semesters of IPRO 337's green energy research. We also had a sub-goal of researching interior lighting techniques using radiant painted walls. The wind turbine objective was approached by first researching various designs to examine the feasibility of each, three designs were selected. A small scale test model was then created to test the efficiency of each model at producing the most energy. The most efficient design was then selected to become the prototype for the large scale model. The team moved into a design development phase, where designs and material choices were considered. Materials were then selected and purchased and construction began. The next phase is testing of the full scale model in an exterior condition and recording actual amount of energy produced. The accumulation of data from the previous semester of IPRO 337 began with the raw extraction of data. The group then identified green energy concepts that would be helpful in the design of a new IPRO facility. The information was then complied into a booklet format that could be easily reference when needed. The booklet could then be given to the design subgroup and components could be chosen to enhance the green energy aspect of a building. The last sub-goal was mainly in a research stage with some tests conducted with on hand materials. The time did not exist this semester to fully develop this concept.

The Building Feasibility sub-team had two primary tasks during the semester. The first was to gather data regarding the current state of the CTA building on campus. The second task involved organizing this data and using it to develop an energy model. This energy model could illustrate how potential changes in the building's infrastructure would affect its energy efficiency.

The team's first step in the data collection process was to use a thermal imager to conduct an air infiltration study. Many images were taken of the CTA building's inside and outside walls, and the temperatures of these walls were recorded. The temperatures would then be used to calculate the R values of the building surfaces. Next, the team visited the facilities office in Machinery Hall and analyzed several technical drawings of the building. These drawings provided pertinent information such as insulation, roof, and wall thickness. Finally, the team entered the building and collected data that was readily available including the number of light fixtures, types of windows, and relevant HVAC information regarding boiler and heating equipment.

After collecting all the information, the team looked into eQuest, an energy modeling software. The data was imputed into the program, and the program quickly generated an energy analysis of the CTA building. The output of this model would then help the team collaborate with the other subgroups to determine if the CTA building could function as a future IPRO space and whether or not the Machinery Hall subgroup's wind turbine could be applied to the building.

The Programming group was tasked with developing a collaboratory space program, and then applying that information to a suitable concept within the constraints of the CTA building. A survey was developed, and distributed to IPRO sub-team leaders and instructors to develop a sense of what the collaboratory space would require in terms of programmatic elements. Later, a set of concepts was developed and adapted to suit both the building and program.

4. Analysis and Findings

For the Zero Energy Lab Team, we built three mock ups of different designs for our turbine and tested them using different resistances. The results are listed below.

T1

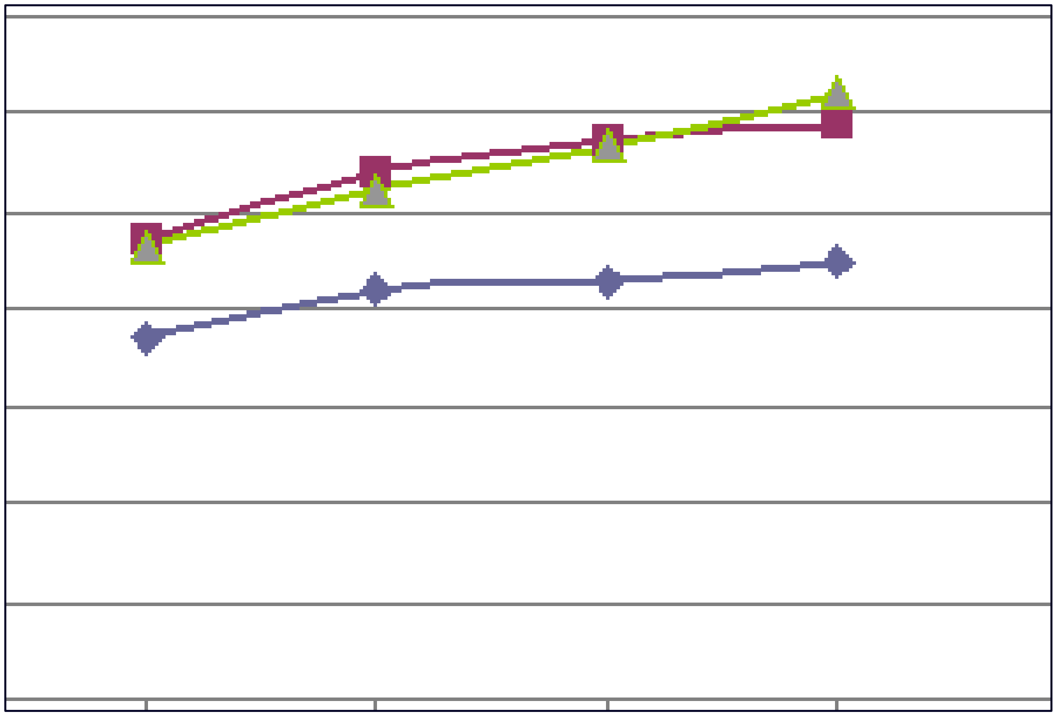
Resistance	Average
100	0.738555556
200	0.835685714
300	0.858142857
400	0.891826087

T2

Resistance	Average V
100	0.93725
200	1.079565789
300	1.143123288
400	1.173219178

T3

Resistance	Average V
100	0.929324324
200	1.0440375
300	1.128797297
400	1.241351351



From the results we decided to go with the T3 design, a savonius wind turbine design with three blades. This design provided equal or higher voltage at each resistance level tested.

The Programming sub-team has made significant gains through analyses and findings. The team found out the types of spaces in which the IPRO program will function most effectively. The survey elaborated the type of spaces student will prefer to work in. Through the site analysis, the teams establish the CTA building is ideal for the IPRO space. The CTA building is flexible, adaptive and in line with the proposed design.

The subgroup had numerous resources with which to work. We conducted interviews, visited and analyzed sites, and created a survey for other sub-teams and IPRO's. We had a constructive interview with Thomas Jacobius, the director of the IPRO program. Through this interview, the team was able to articulate the future and had a feel of the current situation with IPRO. A visit to the University of Illinois-Chicago innovation center gave a good example of how students use space and how they collaborate in such spaces. With a survey, we had questions answered which gave us insight from instructors, students, and sub-team leaders. The data gathered through the site analysis gave a clear picture of what would be the perfect space for the IPRO program. We were additionally able to use input from previous IPRO's to gain more insight to relate to our current objective

The team found out what constitutes an IPRO 2.0 and how to reach such a goal. Students preferred an unrestrictive environment and independent furniture orientation. We found out E1 is currently the most used space on campus for IPRO classes. The team researched the characteristics of this and other frequent spaces. The team found out the peak hours that IPRO classes meet and the most frequent equipment needed.

The Programming sub-team also examined Machinery hall and the CTA building. The team is proposing a remodel design as far as the CTA building is concern. The team is suggesting different spaces such as wet space and dark room. The team is deemed to articulate the flexibility of collaborative space and how students function in these spaces. The survey gave the team a good handle on what has to be done. Collected data is translated into the proposed design.

In order for the Feasibility team to evaluate the CTA building, we decided that we needed to know the "as is" condition of the building and its utilities. We asked Facilities for data on the gas and electricity usage history. We also used a thermal imager to get infrared pictures of the building's interior and exterior walls. In order to help document the infrared data, we needed elevation drawings of the building in AutoCAD but only floor plans existed, so we got blueprints of the building and drafted our own AutoCAD elevation drawings. With these pictures, we can see where the building is losing heat and future IPRO teams will be able to decide where to apply better insulating solutions. In order to get a thorough model of the buildings energy usage our team decided to use eQuest software. In order to get an accurate model, the software needs accurate input of all the buildings properties. To do this, we referenced the building blueprints to get building materials and properties, electrical and lighting plans, we visited the building to specs on the heating and HVAC units. To get help on using eQuest itself, we contacted a professor at the University of Wisconsin. Once all the necessary data is put into eQuest we were able to get a model that shows how much energy is being used and where. With this, future IPRO teams will be able to make changes to the building and simulate the affects it will have on energy usage and costs.

5. Conclusions and Recommendations

Throughout our project the Zero Energy Lab team found that a wind turbine is a type of green energy that can easily be produced by an average group of students at IIT. The ideal materials were not used in the construction due to the fact that it is hard to construct using specialized materials. We have explored trying to incorporate a design experience into the wind turbine. The next IPRO should be able to take the model we have created and test it further. At that point they would be able to redesign the turbine to use better materials and a design concept. The concepts that we have accumulated can be applied to any further designs, and as technologies improve more concepts can be added to be able to be referenced.

Based on the work of the Programming team this semester, our sub-team has concluded that the existing CTA building is appropriate for a new IPRO collaboratory facility. The location and the fact that it is an existing and usable building attribute to this idea. Our sub-team has also created an appropriate program for the building, which includes spaces conducive to collaboratory spaces and the necessary support spaces to let IPRO's work and create with fewer restrictions than the current facilities allow.

To supplement this program, our team used a survey to gather information from students and IPRO professors. We discovered where (E1) and when (3:15 – 4:30) most IPRO's met. We also learned that many IPRO's feel that their projects would flourish if only they had access to certain facilities that are difficult to get in now. However, our program is larger than the existing area in the CTA building (if the second level is built in its entirety), so our sub-team has proposed a spacial solution to the problem in addition to the program.

Since our development of the program and the space within the CTA building has been intense throughout most of the semester, our IPRO would recommend another semester for the design project, to further develop the intricacies of the design and the plan. Because the collaboratory space is meant to be a 'green' showpiece for the school as well, another semester is needed to fully integrate the Zero

Energy Lab concepts with this building design.

Finally, the facilities needed for a future IPRO collaborative space, as found by the Programming group, could be applicable to the CTA building. The building itself could also be improved to consume less energy by both improving the skin of the building and installing new zero energy technologies. Our recommendations for a future IPRO team are to deepen the knowledge of zero energy technologies and how they are physically installed.

6. Appendices

Programming team
Kai Hansen, Theresa Zappala, Lillian Park, Abraham Akutagawa, Teddy Mensah

Zero Energy Lab team
David Babnigg, Jay Patel, Mark Chiu, Konrad Kawa, Jon Reinecke

Feasibility team
Evan Vice, Brian Parkes, Benton Dosky, Clayton Shive

Resources
Survey Monkey, Google maps, eQuest, IPRO 328 (Fall 2008)

Contacts
Thomas Jacobius, IPRO director, IIT
Keith Swartz, Energy Engineer, Energy Center of Wisconsin

Budget

Part Description	Date of Purchase	Location of Purchase	Quantity	Cost Per ($)	Total ($)	Total with Taxes/Shipping	Type of Payment	Purchased By
Improved-Strength Basic Aluminum (Alloy 3003), .025" thick, 24" x 36"	10/29/2009	McMaster-Carr	3	16.04	48.12	54.12	Credit Card	Jonathan D. Reinecke
Steel Thrust Ball Bearing Steel, for 1" Shaft Diameter, 1-5/8" OD	11/11/2009	McMaster-Carr	2	5.79	11.58			
Bimetal Hole Saw 1-1/4" Diameter, 1-1/2" Cutting Depth	11/11/2009	McMaster-Carr	2	4	8			
Arbor for 1-14" - 6" Saws, 5/8" Diameter, Hex	11/11/2009	McMaster-Carr	1	9.57	9.57			

Steel Needle-Roller Bearing Double Sealed for 1" Shaft Diameter, 1/4" OD, 1" Width	11/11/2009	McMaster-Carr	2	12.81	25.62			
Multipurpose Aluminum (Alloy 6061) 1" Thick, 2" Width, 1' Length	11/11/2009	McMaster-Carr	1	13.09	13.09			
Low-Carbon Steel Tubing 1" OD, .76" ID, .120" Wall Thickness, 6' Length	11/11/2009	McMaster-Carr	1	20.26	20.26	94.12	Credit Card	Jonathan D. Reinecke
Motor	11/12/2009	Chicago Store Customer	1	57.5	57.5	63.39	Credit Card	Konrad
11/4 FNDWSCa#?????	11/14/2009	Home Depot	1	4.37	4.37			
Coner Brace	11/14/2009	Home Depot	10	2.49	24.9			
Fitting	11/14/2009	Home Depot	4	5.21	20.84			
1 X 2 Nipple	11/14/2009	Home Depot	8	1.22	9.76			
Platbaggds????	11/14/2009	Home Depot	10	0.98	9.8			
Washers	11/14/2009	Home Depot	1	4.24	4.24	81.49	Credit Card	David
1/4" x 2 Hexbolt	11/18/2009	Home Depot	8	0.18	1.44			
1/4" x 11/2 Hexbolt	11/18/2009	Home Depot	8	0.16	1.28			
1/4" Hexnuts	11/18/2009	Home Depot	18	0.06	1.08	4.19	Debit Card	Mark Chui

eQuest Results
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Survey Results
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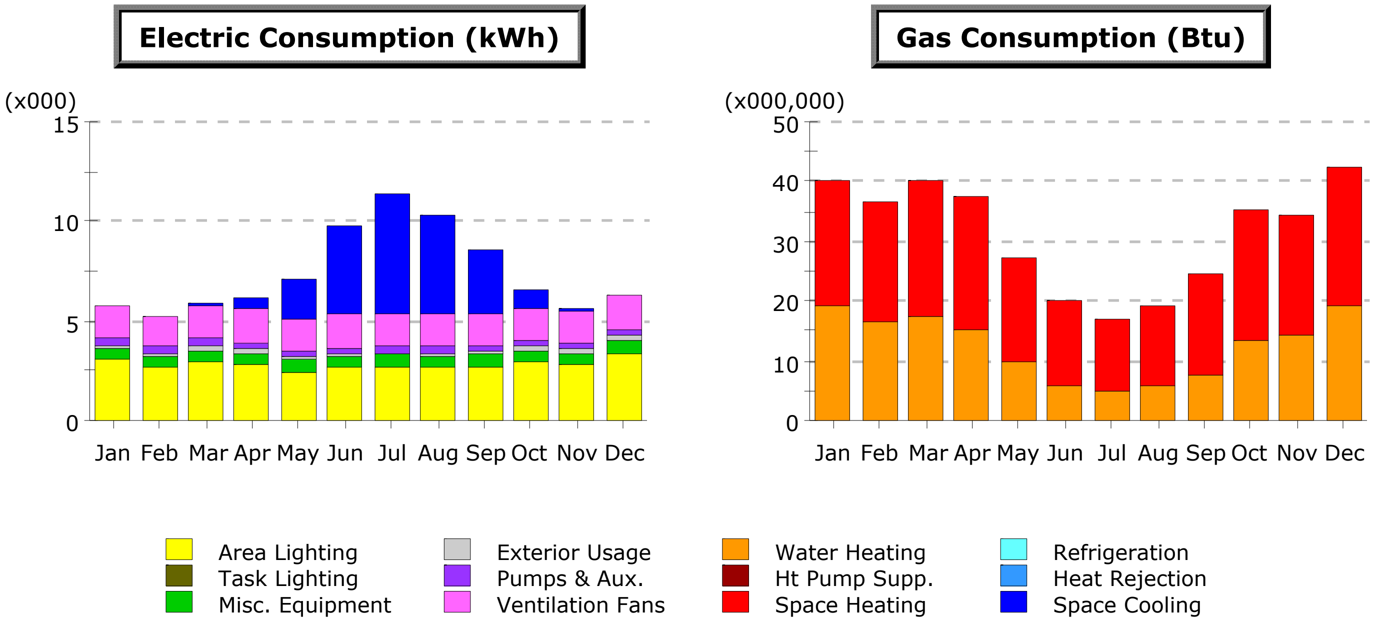


Electric Consumption (kWh x000)

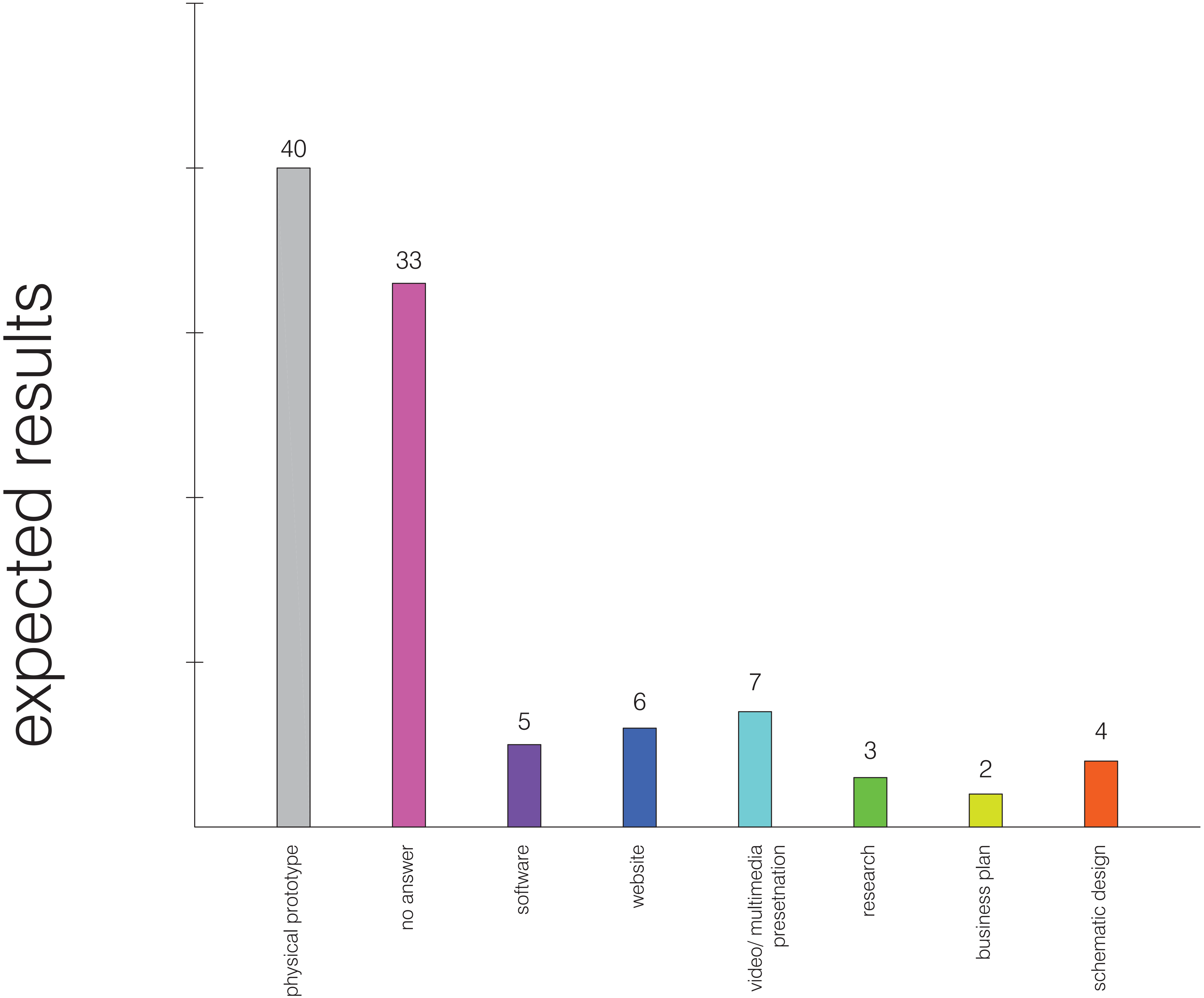
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	0.06	0.49	2.08	4.40	5.93	5.03	3.20	0.84	0.15	-	22.17
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	1.57	1.49	1.73	1.73	1.57	1.73	1.73	1.65	1.65	1.65	1.49	1.73	19.72
Pumps & Aux.	0.39	0.36	0.39	0.35	0.31	0.27	0.28	0.28	0.28	0.33	0.37	0.39	3.99
Ext. Usage	0.20	0.15	0.17	0.16	0.12	0.11	0.12	0.19	0.18	0.19	0.19	0.20	1.99
Misc. Equip.	0.56	0.53	0.61	0.61	0.56	0.61	0.61	0.59	0.58	0.59	0.54	0.61	7.01
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	3.04	2.67	2.92	2.79	2.47	2.67	2.69	2.64	2.72	2.91	2.84	3.41	33.77
Total	5.77	5.20	5.88	6.12	7.11	9.80	11.36	10.37	8.63	6.50	5.58	6.34	88.66

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	21.13	19.94	22.98	22.68	17.51	14.29	11.84	13.45	17.01	21.90	20.17	23.40	226.29
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	19.14	16.48	17.29	14.96	9.85	5.84	5.12	5.75	7.55	13.44	14.15	19.21	148.81
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	40.27	36.42	40.27	37.65	27.36	20.14	16.97	19.20	24.56	35.35	34.32	42.61	375.10

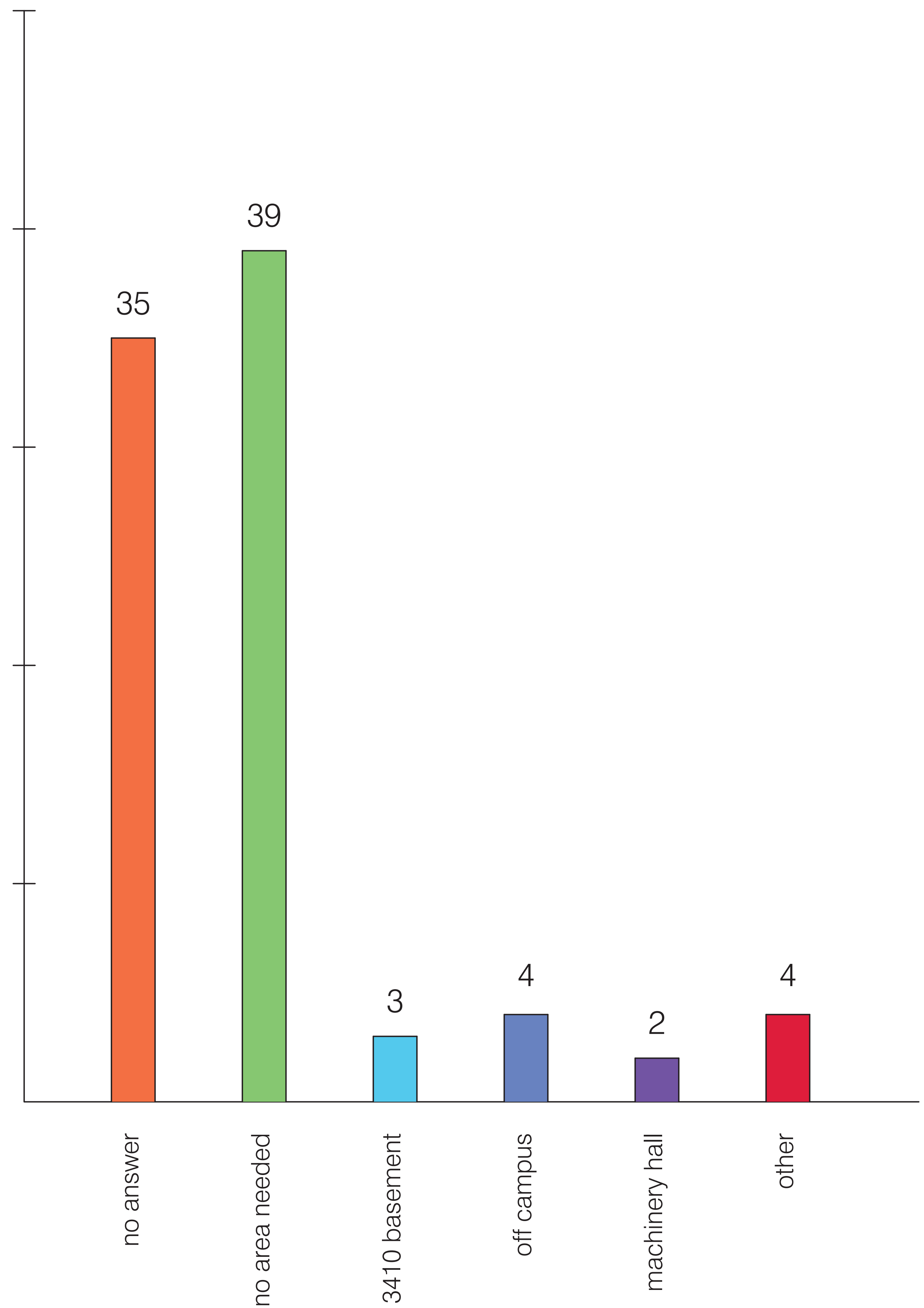
survey analysis

‘making’



expected results
40
33
5
6
7
3
2
4
physical prototype
no answer
software
website
video/ multimedia presetnation
research
business plan
schematic design

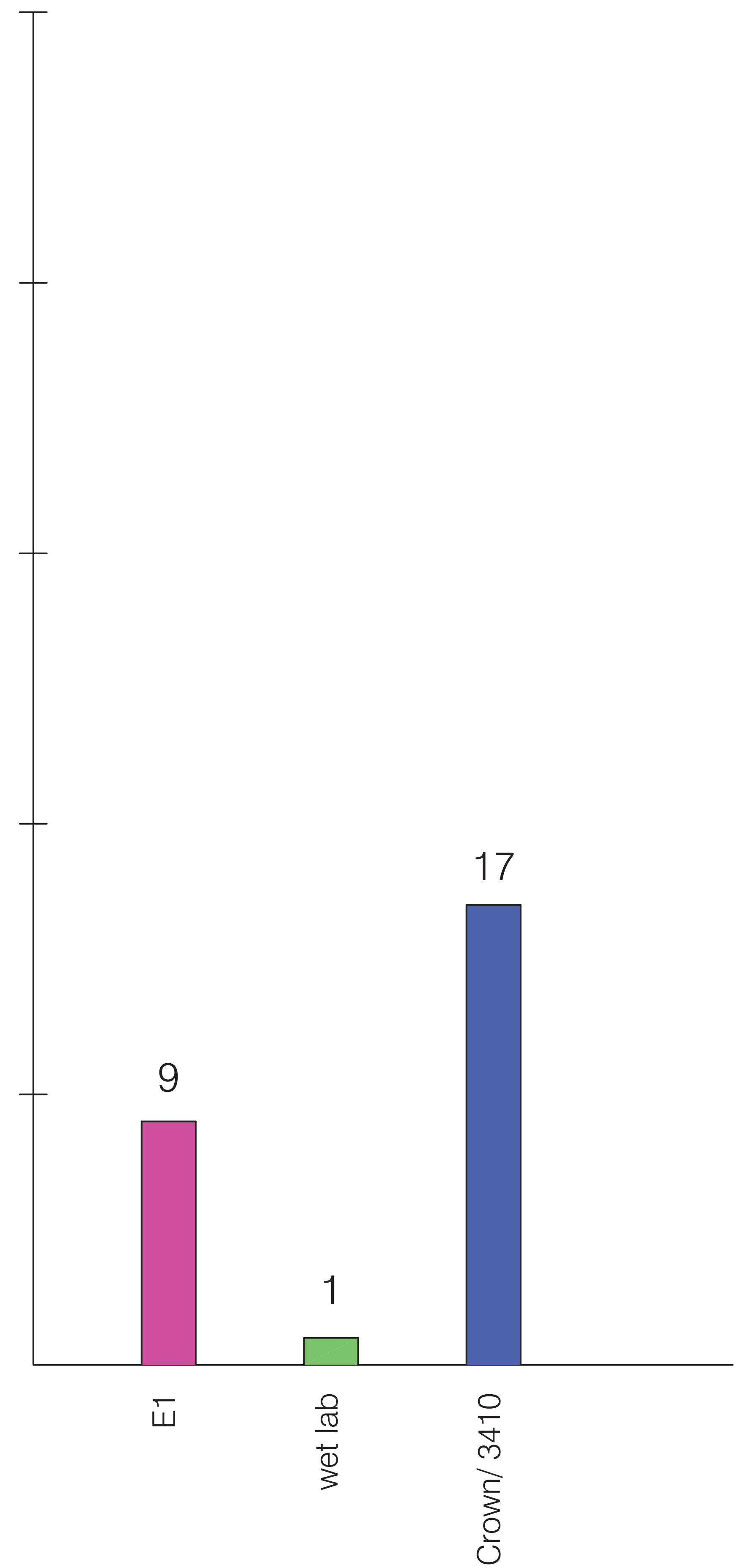
staging areas



other on campus areas

Delta Tau Delta
E1 Machining Lab
Crown Hall
Siegel Hall

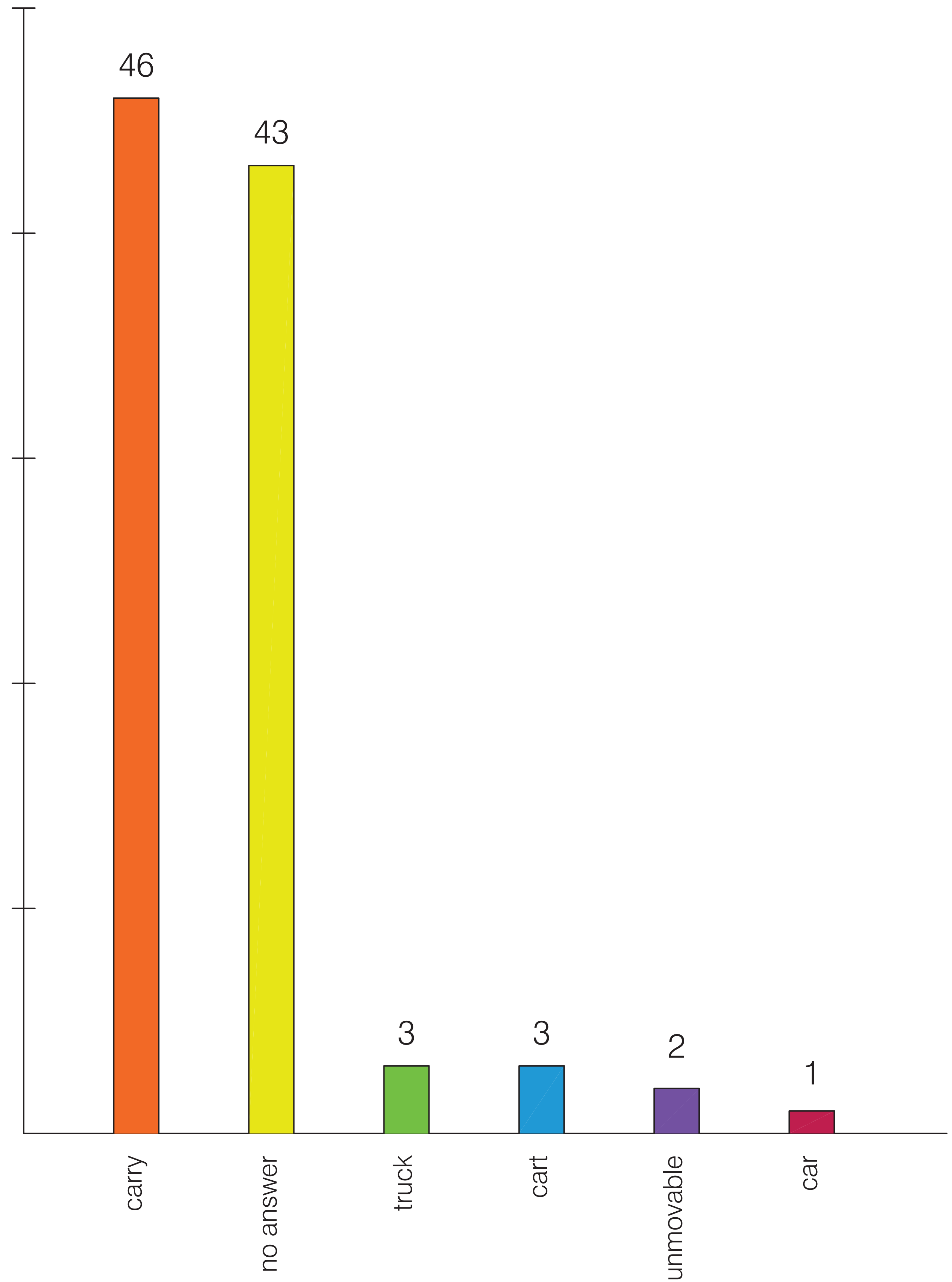
machine shops



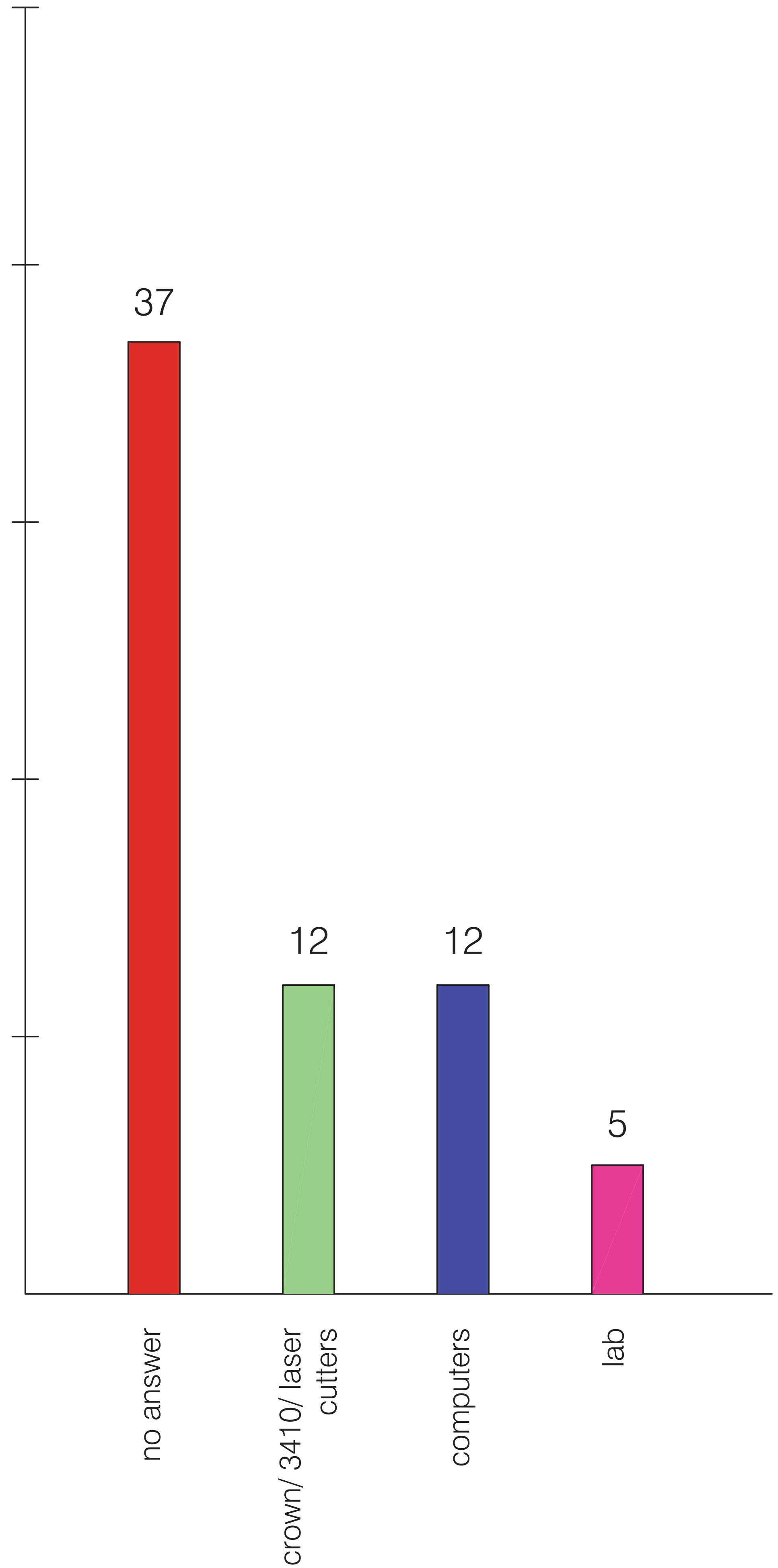
Shop equipment people use/need

Drill press
Table saw
Band saw
Laser cutter
Miter saw
Soldering iron
Heating ovens
Drills, pliers, torches, c-clamps
Bridgeport

transportation



useful facilities/ equipment



Roadblocks to making progress:

Lack of a suitable place to work with electronics
Lack of lab hours and difficulty of obtaining them
Lack of storage
Lack of nearby/ available/ up-to-date prototyping shop
Poor projection equipment

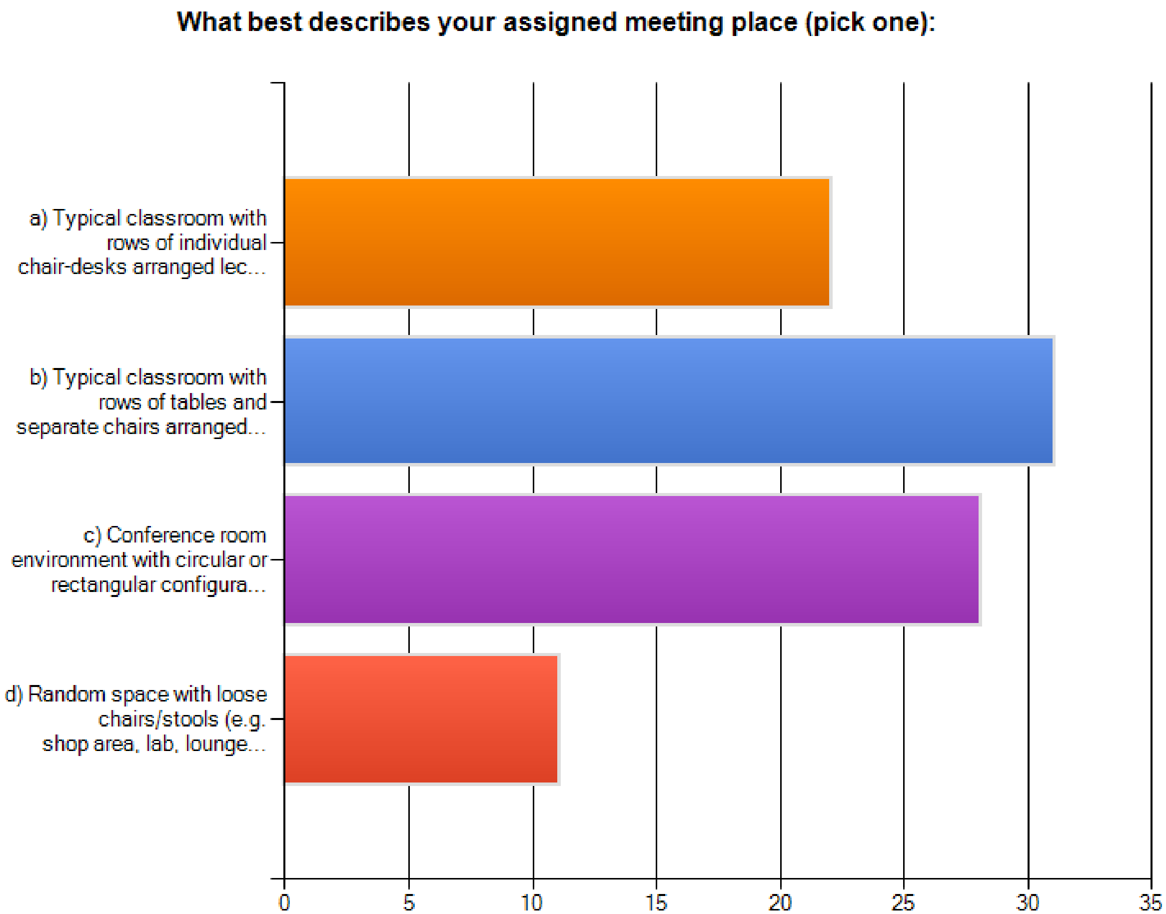
What amenities would help improve an IPRO space?

Video conferencing, for absent members
Sufficient outlets for computers
Electronic white boards – ‘smart boards’
A prototyping shop separate from Crown/3410 (14)
A lab for electrical equipment
Dedicated IPRO servers
Dedicated pin-up space, central for IPRO teams
Storage lockers

CLASS ROOM SURVEY

PROGRAMMING

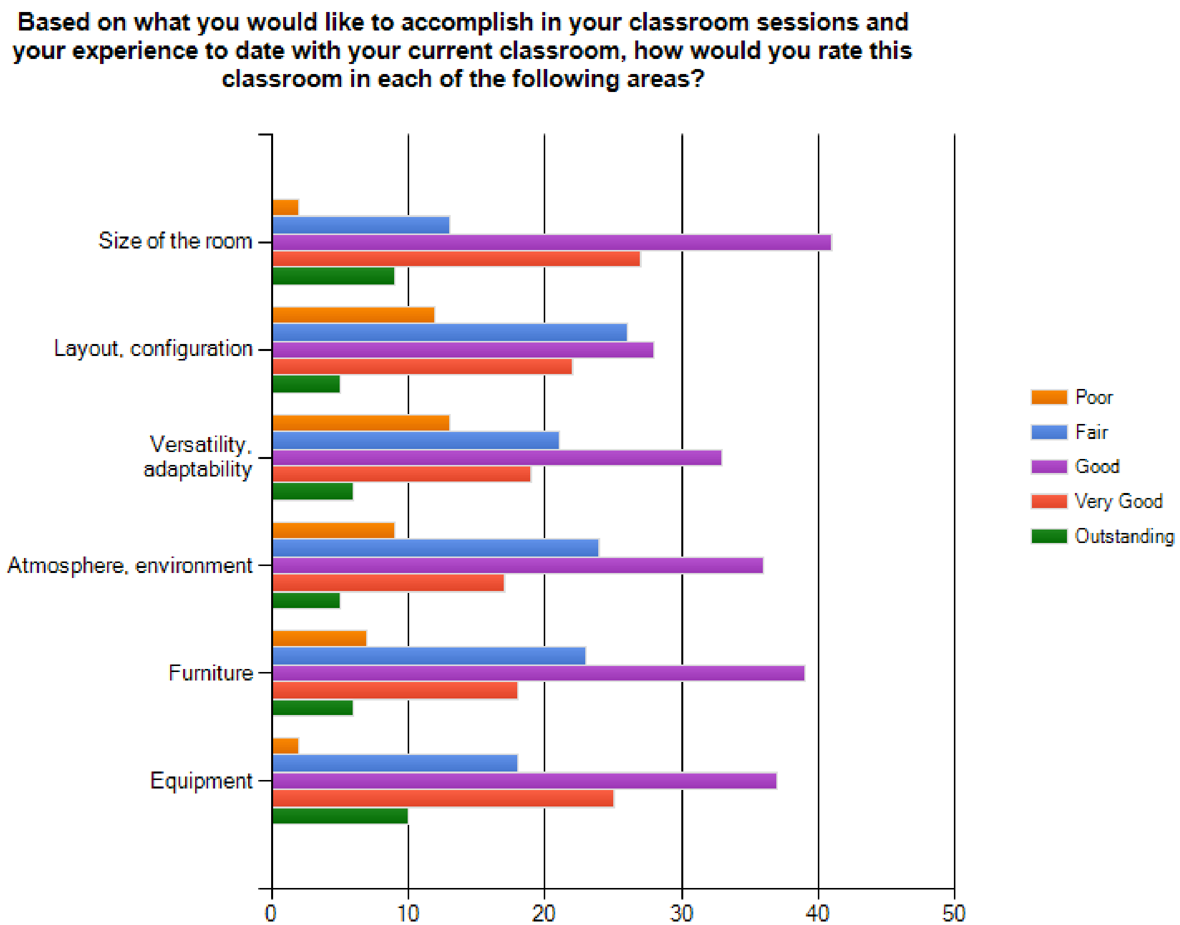
CLASS ROOMS



A CONFERENCE ROOM ENVIROMENT WITH SEPARATE CHAIRS AND TABLE SEEM IDEAL FROM SURVEY DATA

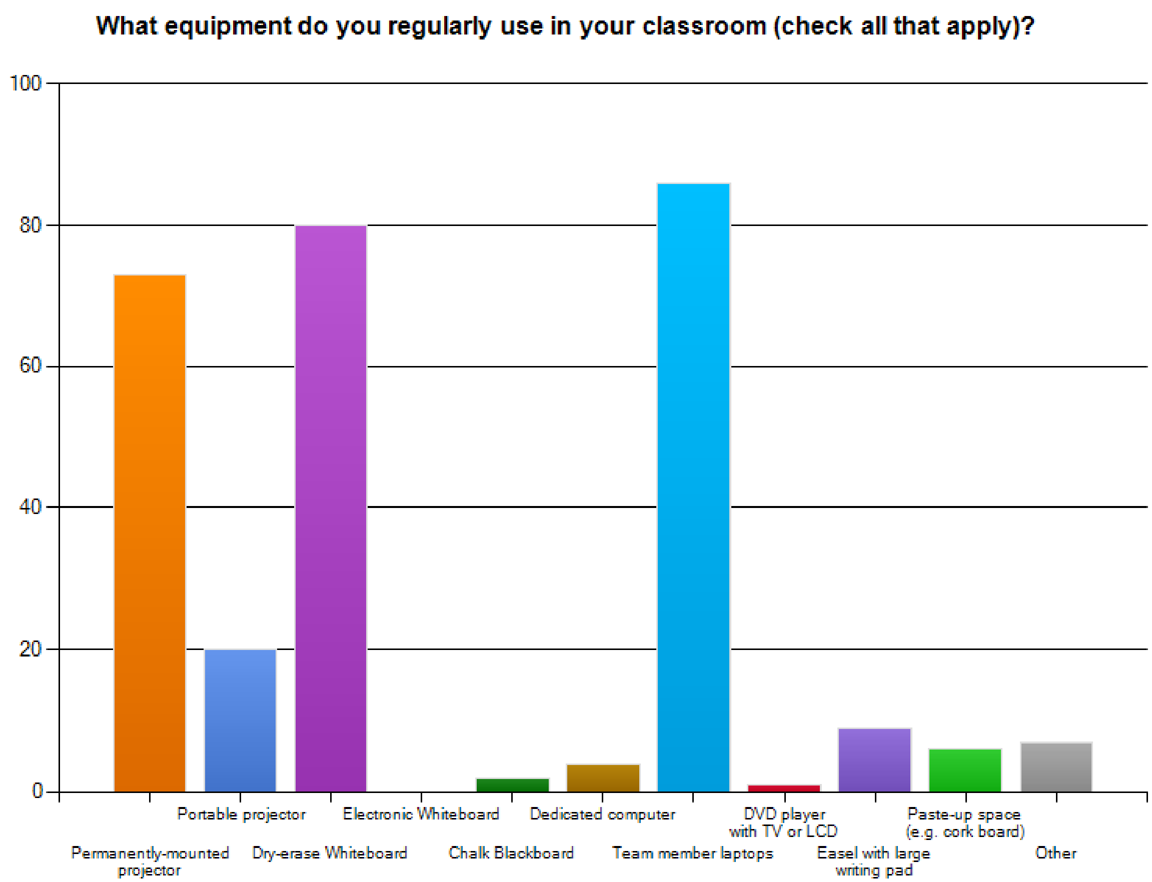
A FOLLOW UP QUESTION; HOW ARE CLASSES STRUCTURED? RESULTS ARE, 91% DISCUSSION, 89% LECTURE STYLE AND 90% BREAKS INTO GROUPS

CLASS EFFECTIVENESS



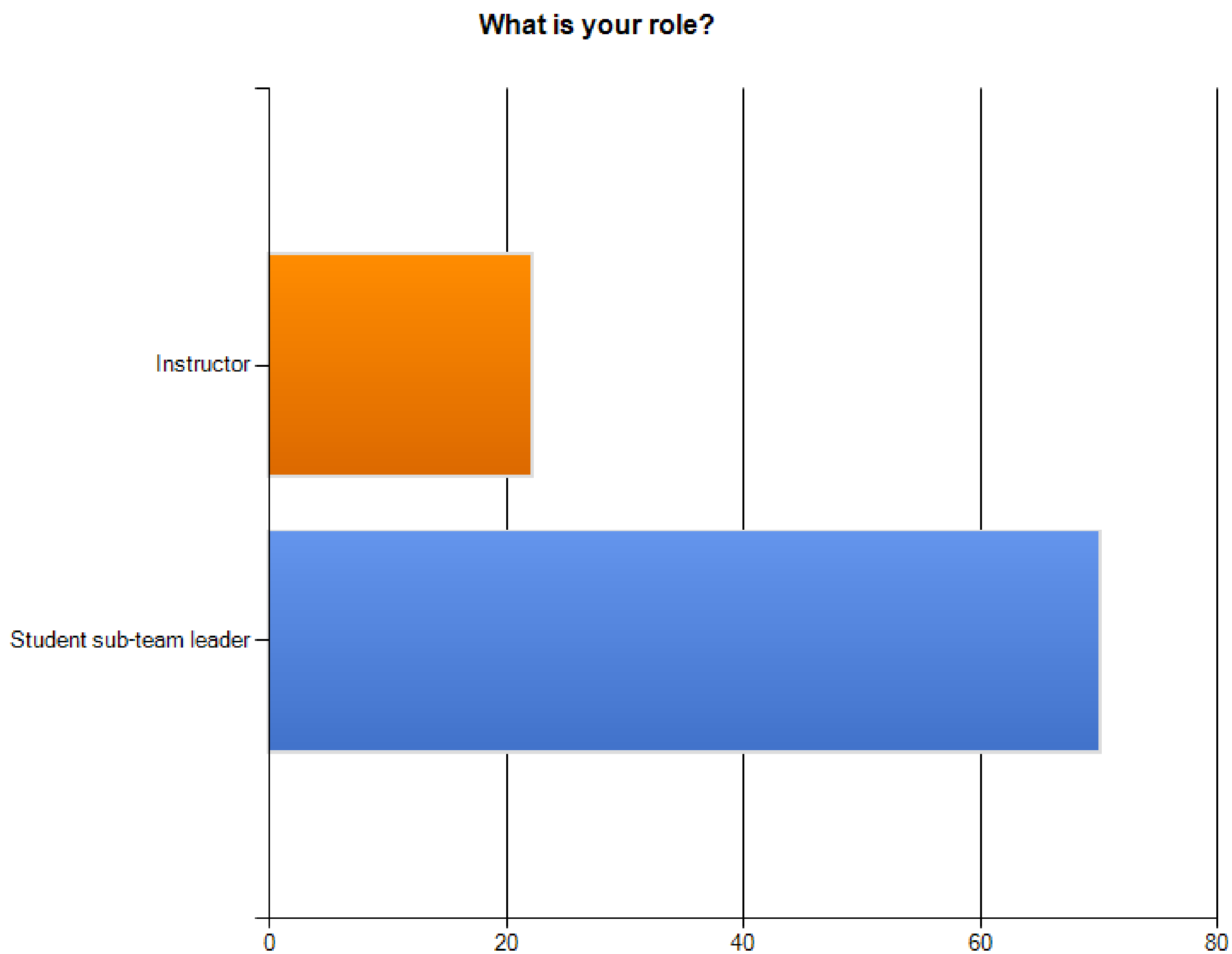
A CLEAR SENSE OF CHANGE NEEDED. ON ALL OF THE ISSUES, THE SATISFACTION RATES ARE LOW. NON RESTRICTIVE STYLE SPACES ARE IMPORTANT BECAUSE MOST IDEAL PLACE CHOOSEN LIKE CROWN HALL OR MTCC FALL IN SUCH CATEGORY

CLASS EFFICENCY



DRY ERASE WHITEBOARD IS THE MOST USED. ALTHOUGH TEAM MEMEMBER'S LAPTOP IS HIGH.

PARTICIPATION

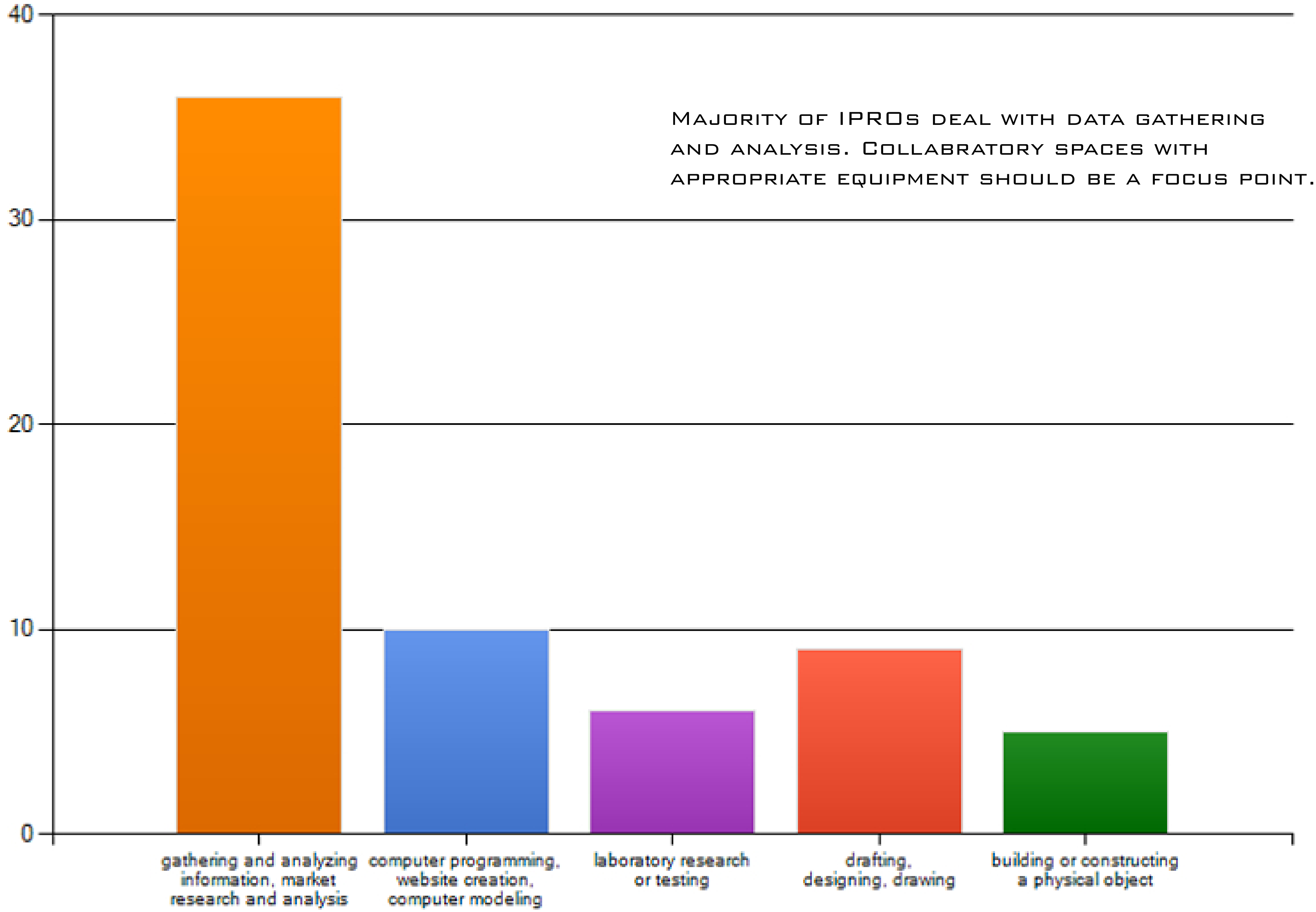


SUB-TEAM LEADER PARTICIPATION IS HIGH. IS KEY BECAUSE OF THE ROLE.

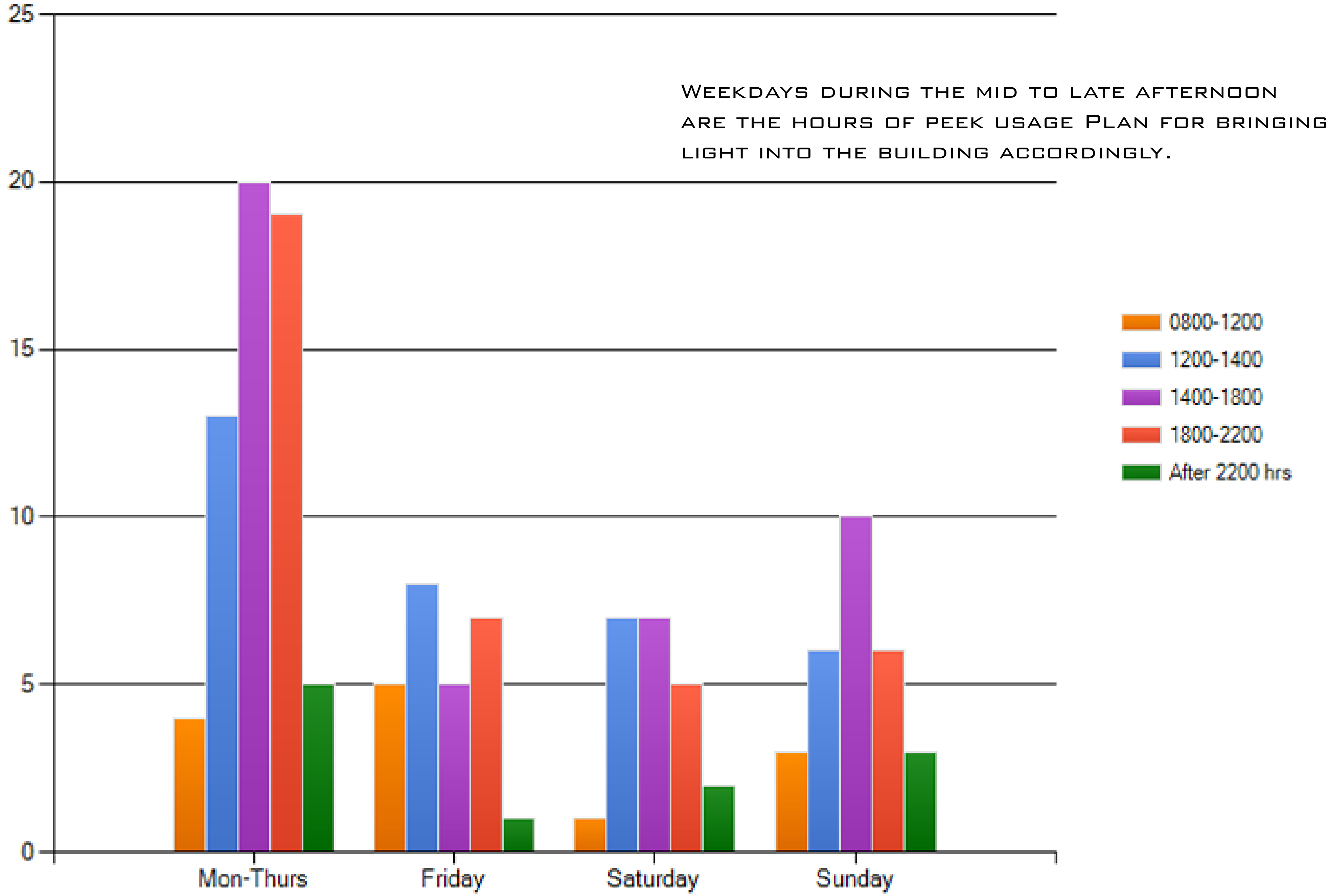
OBSERVATION FROM SUB TEAM MEETING PLACE SHOWS 42.2% GOOD, 39.1%VERY GOOD

AGAINST 1.6% POOR. IS CONSIDERABLY VERY RELEVANT

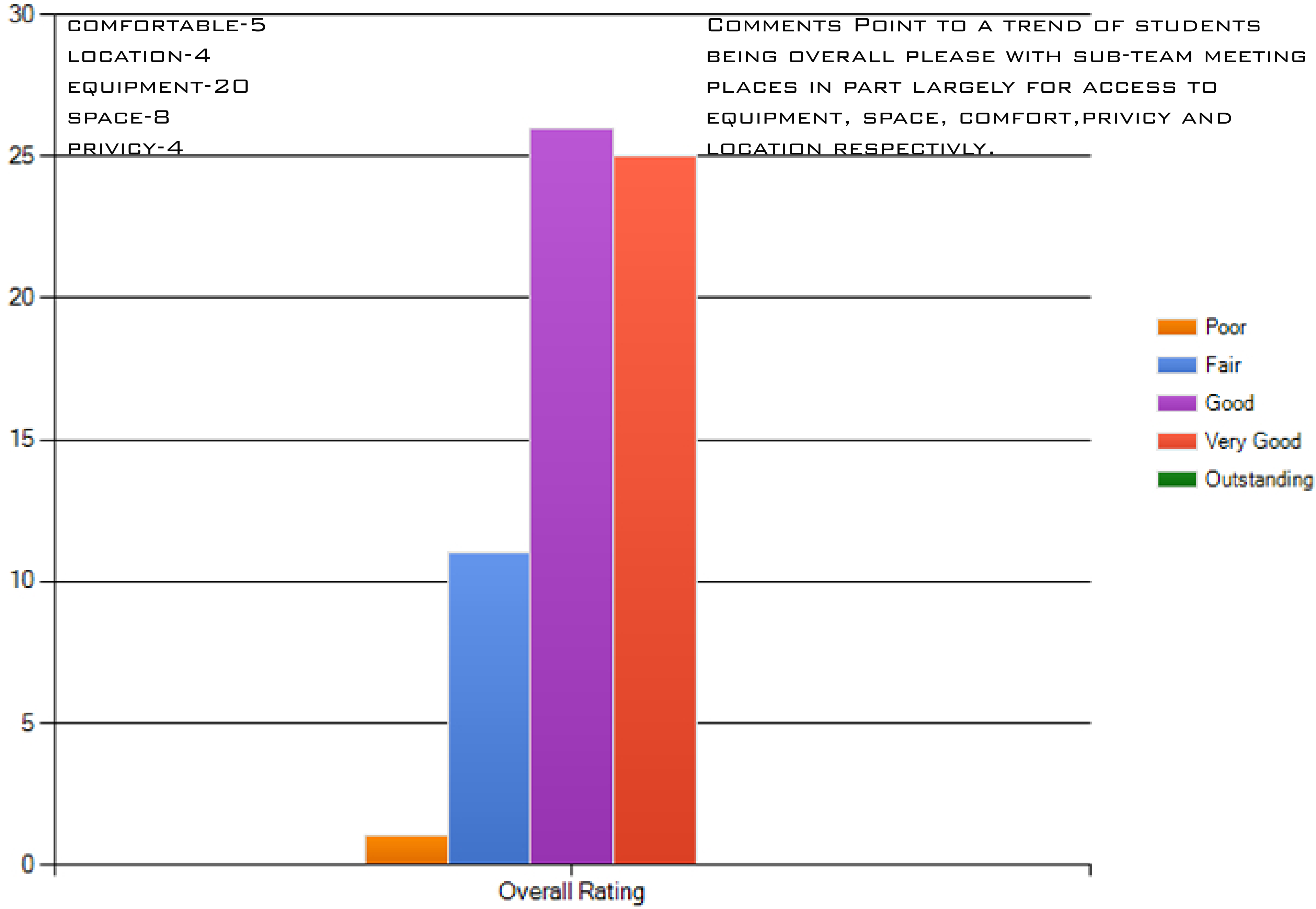
Which best describes the nature of your sub-team's role:

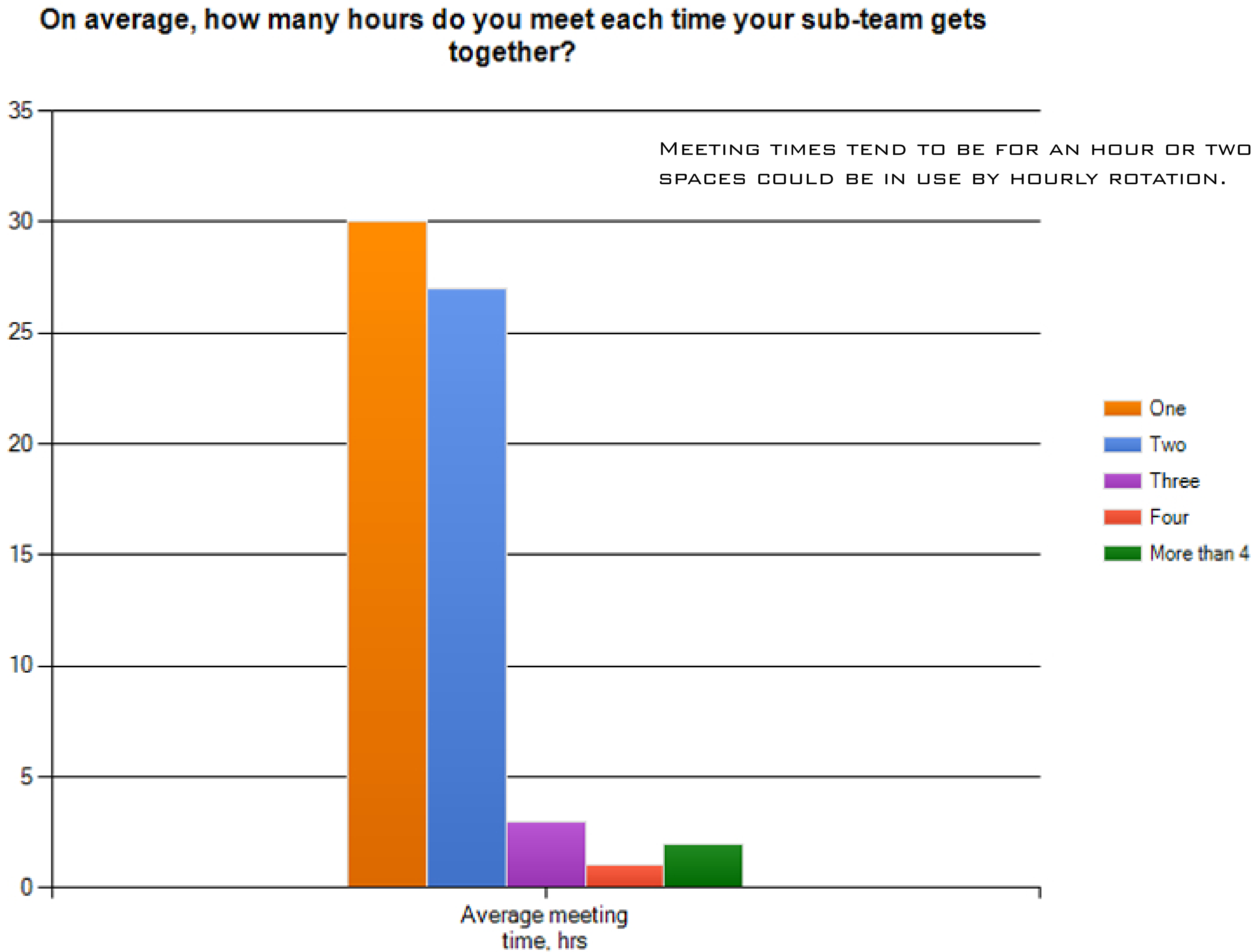


What is the preferred day and time for your sub-team to meet outside class hours:



For what you want to accomplish in your sub-team meetings how would you rate your sub-team meeting place?




On average, how many hours do you meet each time your sub-team gets together?
Meeting times tend to be for an hour or two
spaces could be in use by hourly rotation.
35
30
25
20
15
10
5
0
Average meeting time, hrs
One
Two
Three
Four
More than 4