Technological Turnover and Electronic Waste Management on a Green Campus

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ABSTRACT

Proper management and reduction of waste streams is a key focus of sustainability. The University of California at Berkeley has an initiative focusing on reducing waste and diverting as much waste from landfills as possible. Progress toward complete diversion from landfills has been especially slow in the case of electronic waste (e-waste). This study sought to understand the degree to which lack of awareness of e-waste and campus e-waste policies account for the shortfalls of e-waste diversion goal. I examined the UC Berkeley library system to see how information about sustainability and waste disposal policies are received by various branches, and to gauge compliance with that policy. I surveyed library staff members to assess their general e-waste literacy and practices. The results of the surveys contradicted the expected results for the majority of the data set. A little over half of the respondents knew what e-waste is, and approximately a quarter of respondents knew how to properly dispose of e-waste. Further, it was found that small peripherals made up the bulk of frequently requested new electronics. These items were the same ones that were most frequently found in trash intended for landfills rather than being sent for proper e-waste disposal. When combined with the lack of information on proper e-waste disposal, the role that knowledge plays in efficacy becomes apparent. Increased awareness of what e-waste is and proper disposal policy has the potential to significantly decrease the size of the e-waste stream at UC Berkeley.

KEYWORDS

e-waste, University of California Berkeley, sustainable waste management, campus sustainability, libraries

INTRODUCTION

Electronic Waste (e-waste) is a growing global problem. As electronic devices are becoming more commonplace, more e-waste is generated, with Americans throwing out over 400 million tons of e-waste annually (Plambeck and Wang 2009). In countries such as India, the amount of e-waste generated from cell phones alone is projected to increase 18 times by 2020 (Fela 2010). Individual electronic components can contain up to 60 different elements within them, and across all different categories contain over 1000 different substances which fall into either hazardous or non-hazardous waste classifications (Fela 2010, Pinto 2008). Improperly discarded e-waste can have severe consequences for the environment, including degradation of soil quality and air pollution (Fujimori et al. 2012, Nguyen et al. 2009, Robinson 2009). Better handling and improved recycling techniques are required to prevent e-waste from becoming an even more severe issue.

Recycling is not a process that by itself can manage the entirety of the e-waste stream. Only about 25% of the total waste generated is able to be properly processed when recycled given current institutions and infrastructure, with the rest ending up in landfills (Araujo et al. 2012). There are methods to reclaim more e-waste, which can mitigate the problem more completely, such as those seen in areas where resources are scarce and almost all components of e-waste are reused in some way (Lewpawsky and Mather 2010). In other regions of the world, there are programs in place to restore electronics and allow them to be resold at an affordable price (Senior 2009, Lepawsky and Billah 2011). In many places there are plans being established to reduce e-waste as a hazardous waste stream.

The University of California, Berkeley, has a zero-waste initiative designed to divert all hazardous waste from landfills by 2020. In 2010, the plan briefly mentions that the campus was now planning to recycle e-waste (McNeily 2010). However, the initiative is behind track based on their own standards and is still making progress on reaching their initially planned goal of 75% reduction by 2012 (McNeily 2013). UC Berkeley policy has not been clear on how e-waste will be reduced beyond recycling. The campus sustainability report simply states that the campus has been recycling when it comes to the subject of e-waste, while giving more detailed information as to how other forms of waste reduction efforts are underway such as water use reduction. (McKanna and McNeily 2009, McNeily 2010, Sugarman 2011, McNeily 2013). It mentions a hazardous waste

and waste minimization plan that cannot be found outlined in any of the other sustainability resources or information. (McNeily 2013). By having more policies in place to encourage "Reduce, Reuse, Recycle" and to decrease the amount of e-waste generated, it is more feasible to have an effective program. There are no detailed guidelines on the issue of e-waste reduction on campus and no statistics about how much e-waste has been diverted from landfills. The lack of a transparent process brings up the need to further investigate the issue, and see why the campus has been neglecting this hazardous waste stream.

The main question asked was what role knowledge of e-waste and disposal policies plays in the effectiveness of sustainable methods of e-waste disposal. I determined if UC Berkeley had a plan to dispose of their e-waste in an environmentally sound manner, and whether or not the plan was received by the individual departments on campus. I sought to understand how this plan was being executed by the various departments on campus. Were there ways to improve the plan? It was expected that the campus did not properly carry out their e-waste reduction plan, and that it was not being followed by the various departments on campus. The data collected such as examining the various resources being used helped to find out what the campus was actually doing. It focused on the library system, and investigated their usage of electronics and how much turnover there was to see if they are following the sustainability goals. The overall goal of the data collection was to find any areas to improve the plan in place.

METHODS

Study system

The University of California, Berkeley has been making a large push towards sustainability, and makes a perfect site to study e-waste management policies. It is the home to over 32 different branch and constituent libraries. There are over 26,000 undergraduates and over 10,000 postgraduates who have access to these libraries. They are spread across the 178 acres of the main campus, as well as off campus locations such as the Northern Regional Library Facility in Richmond. In addition, the University has affiliations with other libraries and partners with them through Inter Library Loans. With initiatives such as the zero waste by 2020 goal, the campus is looking to increase how much waste is being diverted away from landfills while decreasing the amount of waste generated overall. The various branches of the library system are just one part of

the University, but the differences in their composition and subject areas allow for a wide range of responses to my questions about e-waste management.

Data collection

I surveyed the employees of the libraries about their knowledge of e-waste to see how well these policies had actually been enforced. To learn if e-waste was being handled in different ways, I looked at branches of various sizes spread all over campus and of varying size. In order to ensure that I had a wide variety of responses from a diverse range of participants, I had the survey distributed to every branch with a circulation department using Google Forms. The surveys were conducted anonymously, and participants were emailed an invitation to the survey through the master Library Circulation mailing list. Responses were collected over a two week period.

These departments were chosen in order to have responses from people who had different areas of focus and services provided based on the subject matter they were more relevant to. For example, it would allow for a look at how STEM related branches, such as Engineering and Math/Statistics, handled their e-waste as opposed to branches of the library focused on humanities, like the South/South East Asian and Art History libraries. Demographics and position within the library were taken into account as well. This would indicate whether students or career staff were more knowledgeable about sustainable waste disposal, and to see if there was a specific age range that showed the most knowledge about policies. Career staff was broken up even further into a category of supervisors and normal staff, to further differentiate knowledge based on position.

Data analysis

To group my data, I separated and coded everything based on where it was collected from, and what type of data it contained in Excel and Google Spreadsheets. Different categories were established, such as age range, position, department, and more. In the event that a respondent fell into more than one category, such as working in two distinct departments, their answers were given equal weighting in each of those categories. This was done in order to more accurately determine how many people per applicable category were able to contribute a response to a category which would have been left empty otherwise. To ensure that those who responded as knowing what e-

waste is responded accurately, they were asked to briefly describe what e-waste is. The answers to this were compared against by standard definition later presented to them, and the responses were either grouped as accurate or inaccurate. To analyze my survey results, I used basic statistics to show what percentage answered a certain way, or how many fell into one of my categories. Relevant and applicable figures were automatically generated by Google Spreadsheets for the unweighted responses. For open ended questions or yes/no responses, the data was converted to binary and then taken as a percent responding one way. These were grouped and displayed by department as the main standard among categories within my figures. For the purposes of this analysis, the category of "normal trash" as a potential waste disposal site refers to standard trash cans in which the waste within is intended for landfills.

Summary

In order to find out how the UC Berkeley handles their e-waste, a growing problem for sustainability. To see why there was not more of an effort to include e-waste in sustainability initiatives and where the policies were lacking, I made a case study of the UC Berkeley library system. I looked at various branches in different departments of the UC Berkeley libraries to see how they differed in size or budget. I wanted to see how those differences might influence the way that new electronics are purchased and if they changed how e-waste is handled.

RESULTS

Demographics

I received survey responses from 23 libraries (Figure 1, Table 1). There was a total of 50 respondents, of which 52% were career staff and 48% were Student Library Employees (SLEs). 50% of the career staff respondents were managers or supervisors, and made up 26% overall (Figure 2). With weighting taking multiple branches that an employee might work at into account, there were a total of 61 respondents that were counted as individuals when taking policy

knowledge into account as opposed to the 50 actually received. Overall, the survey received the majority of responses from the Doe/Moffitt branch which made up 44% of respondents (Table 1).

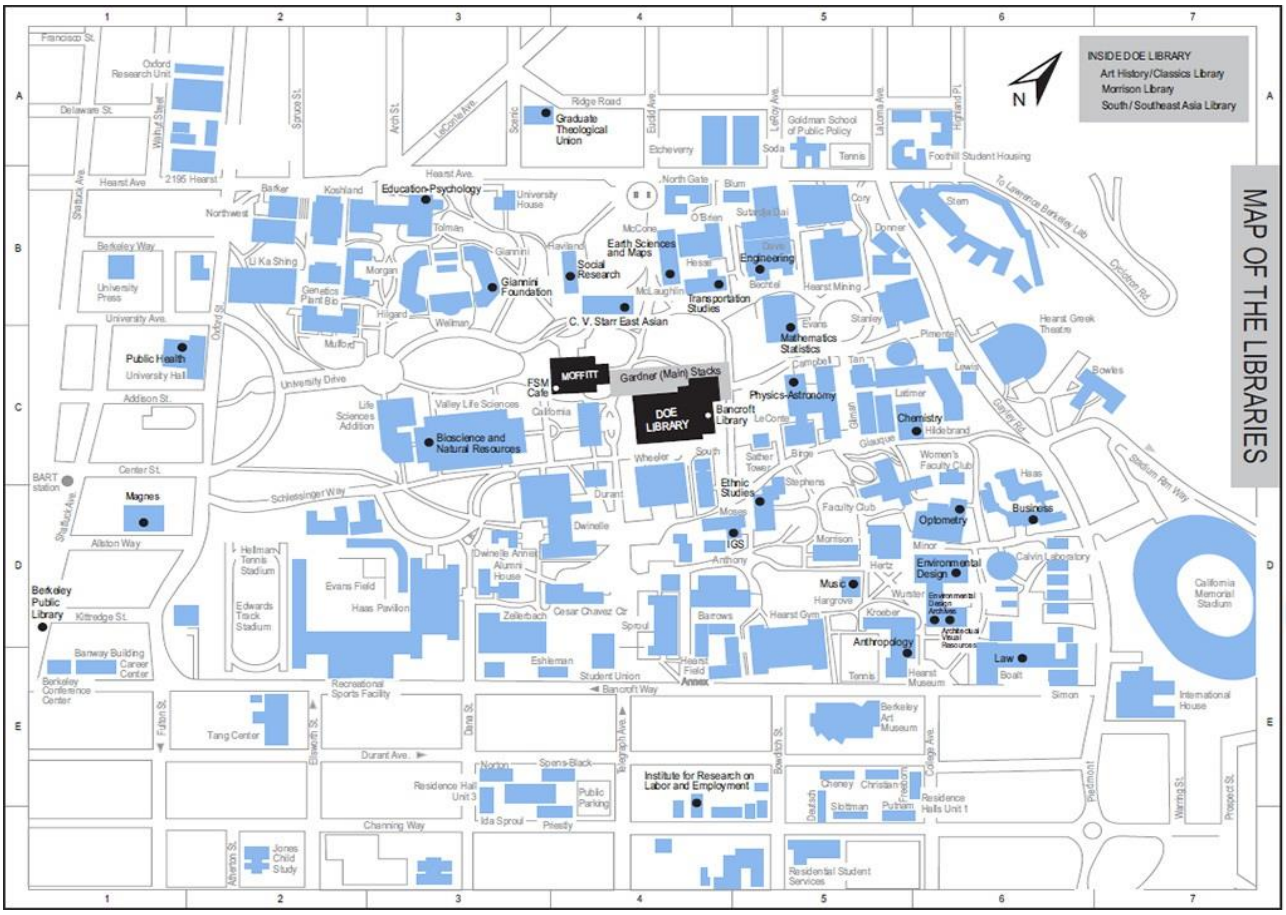

Figure 1. Map of survey sites. Survey sites are distributed all over campus, and the library branches with a Circulation Department were given the survey. Not shown in the image is the Northern Regional Library Facility (NRLF), located in Richmond, CA. Map courtesy of the Library of University of California, Berkeley (www.lib.berkeley.edu/LibraryMap).

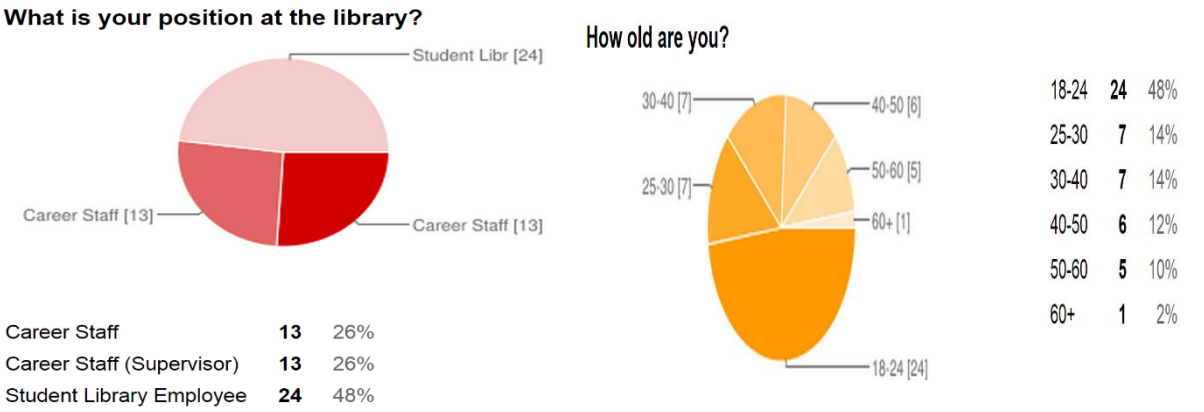

Figure 2. Demographics. Number of employees per category (left) and age groups for the respondents (right) taken from the survey data.

Anthropology	2	4%
Art History/Classics	2	4%
Brancroft	0	0%
Biosciences	4	8%
Business	1	2%
Chemistry	1	2%
Doe/Moffitt	22	44%
Earth Sciences	2	4%
East Asian	0	0%
Ed-Psych	0	0%
Engineering	1	2%
Environmental Design	5	10%
Ethnic Studies	2	4%
Institute of Governmental Studies	1	2%
Institute of Transportation Studies	0	0%
Interlibrary Services	2	4%
Law	0	0%
Math/Stats	2	4%
Morrison	3	6%
Music	1	2%
Newspapers & Microforms	1	2%
NRLF	1	2%
Optometry	2	4%
Physics-Astronomy	2	4%
Public Health	1	2%
Social Research	1	2%
South/Southeast Asian	1	2%
Other	1	2%

Table 1. Survey location responses. Breakdown of number of responses per library that responses were received from. Not all libraries that were sent the survey returned responses.

e-waste Awareness

I found that most employees responded positively in self-reported general e-waste knowledge among library staffs across campus. 56% reported that they knew what e-waste is, or had heard of it before. 44% had never heard of e-waste before, or did not know what it is. Approximately 54% of those who responded that they knew what e-waste is were Career Staff, and the remaining approximately 46% were SLEs. When further examined, it was discovered that despite over half the employees reporting that they were familiar with e-waste, less than half of them knew about e-waste disposal (Figure 3).

A majority of the employees did not know what the departmental policy on e-waste disposal was. 24% reported that they did know what the policy was, while 74% did not know if their branch had a policy, and 2% reported that their branch did not have one at all (Figure 4). The responses that stated that the branch being examined had a policy in place came exclusively from Career Staff and Career Staff Supervisors. Using the weighted responses, it was found that 11 of the 23 branches had a policy in place for e-waste disposal. In the weighted responses, 50% of Career Staff Supervisors did not know if their department had a policy for e-waste disposal.

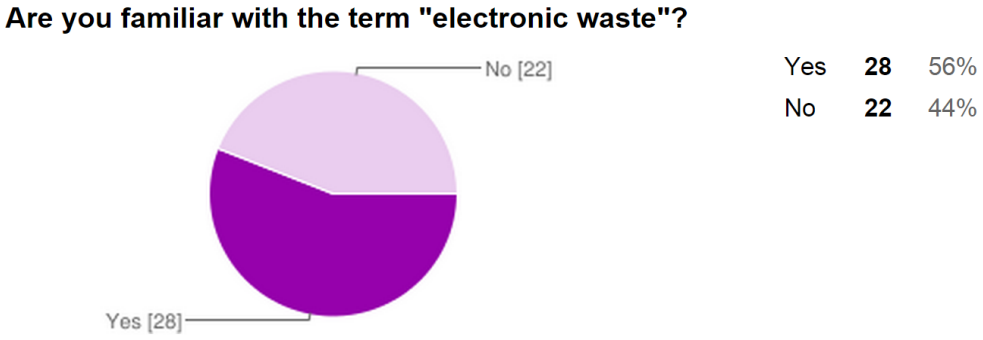

Figure 3. e-waste familiarity. Over half the survey respondents reported being familiar with what e-waste is.

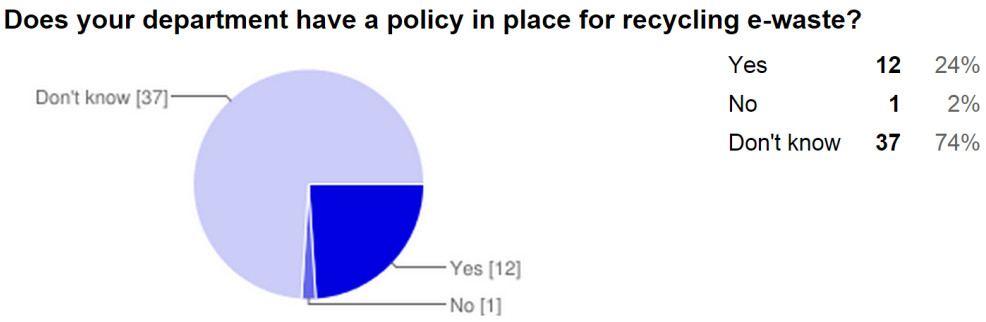

Figure 4. Departmental policies. The majority of respondents did not know if their department had a policy in place for e-waste disposal.

Branch(es)	Age Group	Position
Doe/Moffitt	40-50	Career Staff (Supervisor)
Earth Sciences	30-40	Career Staff (Supervisor)
Chemistry, Earth Sciences, Engineering, Math/Stats, Physics-Astronomy	40-50	Career Staff (Supervisor)
Doe/Moffitt	50-60	Career Staff
Doe/Moffitt	30-40	Career Staff (Supervisor)
NRLF	30-40	Career Staff (Supervisor)
Doe/Moffitt	50-60	Career Staff (Supervisor)
Anthropology, Business	25-30	Career Staff
Anthropology	25-30	Career Staff
Public Health	25-30	Career Staff
Math/Stats, Physics-Astronomy	30-40	Career Staff
Media Resources Center	30-40	Career Staff

Table 2. Departmental policies. The above departments were the ones that had responses of "Yes" when asked if their department had a policy in place for the disposal of e-waste in the survey.

e-waste Disposal

Most employees reported never having seen e-waste mixed into the normal trash, or did not recall personally seeing e-waste there. 36% of employees reported having seen e-waste mixed in with normal trash at some point in time (Figure 5). 68.8% of those employees had seen e-waste mixed in with normal trash at least 1-2 times in the past year, while 12.6% reported having seen e-waste mixed in with normal trash 6 times or more in the past year. 6% of employees knew where to properly dispose of e-waste on campus, or who to call in order to dispose of their e-waste (Figure

6). When asked to rank convenience and ease of access to this disposal site on a scale of 1 to 5, with 5 being the most convenient or easy to access, 33% ranked it as a 3 and 66% ranked it at a 2.

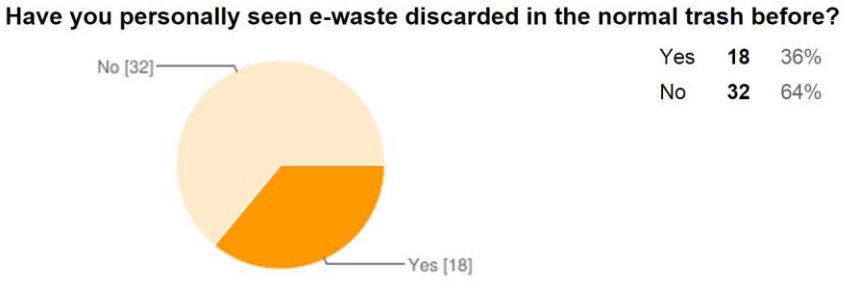

Figure 5. Landfill bound disposal. The majority of respondents did not recall seeing e-waste mixed in with trash that would end up in a landfill rather than being put somewhere to be recycled or diverted away.

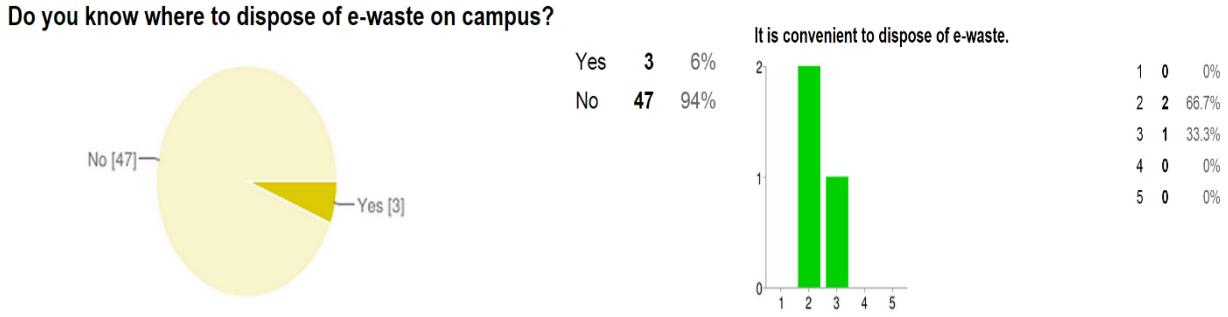

Figure 6. Disposal of e-waste. The majority of respondents did not know where to dispose of e-waste on campus (Left). Of those that did know where to dispose of e-waste, none ranked the convenience of these locations higher than a 3 on a scale of 1-5, where 5 was the most convenient (Right).

Electronics purchasing

I found that electronics purchasing practices were fairly consistent among the different branches. There was a 60-40% split between those who needed to order new electronics and those who did not have to ask for new electronic products, respectively (Figure 7). 86.2% of those who have had to ask for new electronics only needed to do so 1-2 times per year. 75% of those who had a personal work computer needed to request new electronic products. The only instance of someone who required new electronics 6 or more times per year was a Career Staff Supervisor. The majority of electronics that were most frequently ordered by those who did

require new electronics fell into the category of "Small Peripherals", which consisted of mice, keyboards, and barcode scanners. Mice and keyboards were requested the most frequently an equal number of times, accounting for 43.2% of the total requested new electronics. These two items also accounted for the majority of e-waste that was reported being seen in the normal trash before.

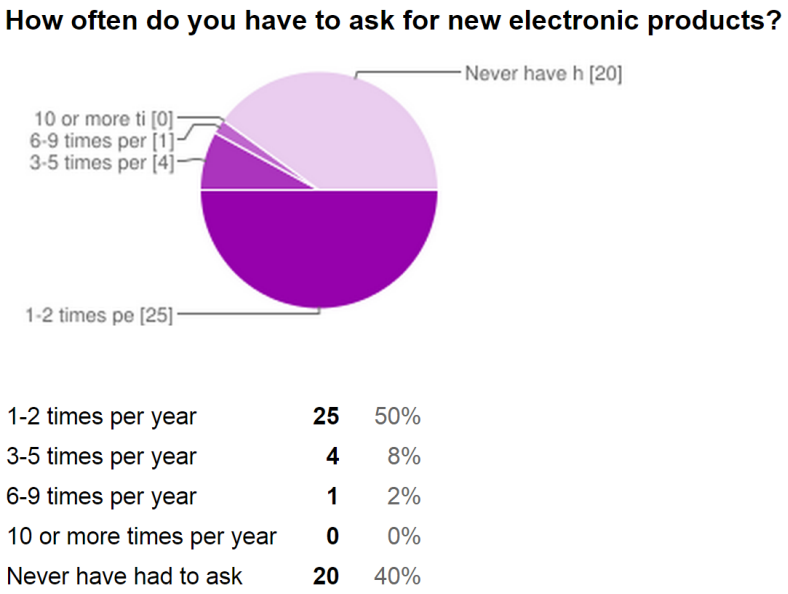

Figure 7. Electronics purchasing frequency. Respondents were asked how frequently they have to order new electronics to gauge rough turnover rates. Almost all Career Staff respondents have had to request replacement items at least once per year.

DISCUSSION

There was a significant difference between expected results and the actual findings about general knowledge of e-waste and sustainable disposal practices. The large number of inconsistencies between the expected and actual results left me with many unanswered questions as to exactly what factors were involved in the way that Library branches dispose of their e-waste. The findings do support the original belief that knowledge of e-waste and e-waste disposal policy is beneficial to increased sustainable waste management efficiency. In addition, the data highlighted different areas to focus on to improve future policy.

E-waste general knowledge

It was expected that there would be a general trend where SLEs were more likely to know what e-waste is as opposed to the Career Staff. However, it ended up being that Career Staff were almost equally aware of what e-waste is. This indicated to me that age was not a factor in knowledge as expected, but rather there were other factors involved in whether someone was familiar with e-waste or not. An interesting result was that half the Career Staff Supervisors did not know if their department had a policy in place for e-waste disposal. Specifically looking at Doe/Moffitt Circulation, half the supervisors responded as there being a policy in place, and half responded as not knowing whether there was one. There was nothing in the data that was collected that can explain why this is the case. What it can reasonably imply is that there is a lack of direct instruction on what the policy is from the heads of departments to others in their branch. Another possibility is that there are so many departments nested within the larger branch overall, it results in inconsistency with how supervisors receive information from the heads of their departments.

Another unexpected result was found when comparing STEM based branches to those focused on Humanities. Looking only at branches which reported having a policy, the branches that I grouped as STEM were Chemistry, Earth Sciences, Engineering, Math/Stats, Physics-Astronomy, and Public Health. In the group of Humanities branches, I included general knowledge branches as well to have Anthropology, Business, Doe/Moffitt, Media Resources, and NRLF as belonging to this category. I expected STEM branches to be more likely to have an e-waste policy in place, however it was a fairly even split once again. Comparing these two categories of Library type, there was no major difference that stood out. Combined with the unexpected results from the different age groups, this supports there being more factors involved in how policy is received by departments.

With the majority of respondents not knowing if their department had a policy for e-waste disposal, it was expected that the majority of respondents would have seen e-waste mixed in with the normal trash before. This was not the case, as most reported not having personally seen e-waste in the normal trash. Even more unexpected was how low the average frequency of seeing e-waste in normal trash was. The average was expected to be much higher, and it was also expected that more people would see e-waste in the trash frequently because of inadequate knowledge of e-waste disposal policy and procedure. This data is however incomplete, as not all employees responded

to the survey and the actual instances of e-waste in the normal trash may be much higher. Alternatively, the reality may be that there is relatively little e-waste that ends up in the trash as a result of those who do know the policy disposing of it properly for others. This may be the case when the supervisors are the only ones who handle ordering new electronics, or seeing if an item is truly broken before attempting to replace it.

Electronics purchasing

In looking at purchasing practices among branches, the results were fairly consistent with what was expected. Smaller electronics made up the bulk of the requests. These smaller peripherals are the items that have the most daily wear and tear on them, and would need most frequent replacing. These items were also the ones most commonly spotted in the normal trash because they were most frequently broken. These results support the conclusion that better purchasing decisions need to be made. If more durable, higher quality items are purchased, they are less likely to break, and would require less frequent replacement. Other decisions can be made that would increase sustainability, such as choosing small peripherals that are made using less plastic, or parts that are more easily replaceable. This would reduce the total volume of waste that is disposed of when the need to dispose of them arises, and allows for easier recycling.

Limitations and future directions

My study system was limited to the UC Berkeley Libraries rather than the campus as a whole, so I cannot accurately apply my conclusion to every department and every building on campus. The survey targeted employees of the Library from all age groups and backgrounds allowing for a diverse range of responses, but it also targeted people who had to answer about wasteful practices at their jobs. This may skew the data, since employees are less likely to report instances of improper waste disposal, especially if they're talking specifically about their own branch. Additionally, the majority of my responses came from one branch, Doe/Moffitt. The time span for the survey was also too short, and should have been expanded. Had I gotten more responses and received something from all libraries, there could perhaps be better way to extrapolate my results and apply it to campus as a whole. There was also no way to accurately track the reality of the day

to day activities at all branches, or monitor trash to see if e-waste was there. Given the time frame, and other limitations, the data does show where improvements can be made overall to decrease e-waste volume before it becomes a larger issue.

This study does show where there is a lack of effort on the part of the campus to meet the sustainability goals they set for themselves. The results support a clear disconnect between staff about policies and standard waste disposal procedures. The Libraries are a huge part of campus, which can safely imply that there may be a similar trend when applied to campus as a whole. The data here gives a good base to start with, and can be expanded in the future across more departments with similar surveys and improved monitoring. The lack of knowledge about disposal procedures at the Library has a simple solution where it can be incorporated into new employee training. There is also a simple solution to the problem that arises from not knowing where to dispose of e-waste yourself on campus; place designated e-waste disposal bins throughout campus that are easily accessible and well-marked, similar to the "Landfill, Paper, and Recycling" bins spread all over the campus. There is also the possibility for the Office of Sustainability and Energy, or the Office of Environment, Health & Safety to conduct similar research on a larger scale using their resources to find a more elegant solution to the problem.

Broader implications

E-waste will continue to grow as an issue as we continue to have "the next big thing in…" released annually. The general lack of knowledge about e-waste itself suggests that e-waste is a problem on campus due to poor availability of information. By taking the libraries as an accurate representation of what we might see on campus as a whole, we see a lack of consistency in policy knowledge and execution of that policy. There is little information about where to dispose of e-waste, which is information that can be easily made available. It is important to try to find a system that can work and on a large scale and ensure that it can be followed. Beyond the obvious goals of reducing hazardous waste flow into landfills and fulfilling the UC Berkeley sustainability initiative goals, the implementation of an effective sustainability plan for e-waste management can be applied in other locations. This can serve as a model for other campuses working towards reducing their waste streams, and can also be scaled up to work for other bodies.

ACKNOWLEDGEMENTS

Thank you to the entire ESPM 175 team for their help and for all they've done for us. Joe was one of the most helpful and instrumental people in the work I've done and I'm grateful for all his help on getting me from "I don't know what I'm doing." to having a completed thesis, making sure I turned stuff in, and for all his advice. Thank you to all the people in ESPM 175 itself for the feedback and supporting each other since 100ES. Shout out to the Super Modelers for being super and obviously the best group in the ESPM 175 cohort. Thank you to the Library Administration for allowing me to survey the library and to Mark Marrow for getting their approval and distributing the surveys to the staff. Thank you to all my coworkers and the other respondents who actually took the survey and gave me data to work with. Thank you to the FSM baristas for keeping me well caffeinated and hooking me up with free coffee and discounts every now and then, which is always greatly appreciated when you're a college student. Lastly thanks to all my friends and my older sister for keeping me sane as I stressed out over every little thing this past year.

REFERENCES

Araujo, M. G., A. Magrini, C. F. Mahler, and B. Bilitewski. 2012. A model for estimation of potential generation of waste electrical and electronic equipment in Brazil. Waste Management 32:335-342.

Fela, J. 2010. Developing Countries Face E-Waste Crisis. Frontiers in Ecology and the Environment 8:117

Fujimore, T., H. Takigami, T. Agusa, A. Eguchi, K. Bekki, A. Yoshida, A. Terazono, and F. C. Ballesteros Jr.. 2012. Impact of metals in surface matrices from formal and informal electronic-waste recycling around Metro Manila, the Philippines, and intra-Asian comparison. Journal of Hazardous Materials 221-222:139-146.

Lepawsky, J., and C. Mather. 2010. From Beginnings and Endings to Boundaries and Edges: Rethinking Circulation and Exchange through Electronic Waste. Area 43: 242-249.

McKanna K., and L. McNeily. 2009. Campus Sustainability Report. Office of Sustainability. University of California, Berkeley, Berkeley, California, United States of America.

McNeily, L. 2010. Campus Sustainability Report. Office of Sustainability. University of California, Berkeley, Berkeley, California, United States of America.

McNeily, L. 2013. Campus Sustainability Report. Office of Sustainability. University of California, Berkeley, Berkeley, California, United States of America.

Nguyen, N. H., T. Agusa, K. Ramu, P. C. T. Nguyen, S. Murata, K. A. Bulbule, P. Parthasaraty, S. Takahashi, A. Subramanian, and S. Tanabe. 2009. Contamination by trace elements at E-Waste recycling sites in Bangalore, India. Chemosphere 76:9-15.

Pinto, V. N. 2008. E-waste hazard: The impending challenge. Indian Journal of Occupational and Environmental Medicine 12:65-70.

Plambeck, E. and Q. Wang. 2009. Effects of E-Waste Regulation on New Product Introduction. Management Science 55:333-347.

Robinson, B. H. 2009. E-waste: An assessment of global production and environmental impacts. Science of the Total Environment 408:183-191.

Sugarman, K. A. 2011. Campus Sustainability Report. Office of Sustainability. University of California, Berkeley, Berkeley, California, United States of America.