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APPLYING DESIGN ROADMAPPING IN NEW PRODUCT DEVELOPMENT EDUCATION: INSIGHTS FROM STUDENT DESIGN TEAMS

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ABSTRACT

A design roadmap is a canvas that facilitates embedding user experience design goals into the earliest stages of the design process by envisioning how a concept can evolve over time to meet changing user needs. This paper explores the development of design roadmap canvases by product design teams in an educational setting. It does so by (1) examining the design roadmapping workshop deliverables from new product development student teams at the University of California, Berkeley between 2014-2017 and (2) analyzing 107 survey responses from students in those workshops about their design roadmapping experiences. The paper describes the benefits to students using design roadmapping and insights into how best to engage students in design roadmapping exercises. Finally, based on the challenges students had with the process employed in the experiment, recommendations are provided to help educators and practitioners make productive use of design roadmaps.

Keywords: design practice, education, design theory and methodology, product development, design roadmapping

1. INTRODUCTION

Many attempts have been made to build structured design processes in support of designers, engineers, design teams and project owners [1, 2]. Technology and product roadmapping processes in particular systematically represent technologies and products to be developed and commercialized over time [3, 4]. Such roadmaps are popular visual communication methods both within and across organizations [5, 6]. Facebook, for example, announces its 10-year roadmaps to the public at its annual F8 Facebook Developer Conference [7] to share the firm's near- and long-term visions and directions. Most roadmaps, however, fail to include direct links from the product, feature and/or technology choices represented to the benefits or outcomes they enable for customers and users. The design roadmapping process aims to facilitate greater input from the designers representing the customer experience to be developed, and more cross-disciplinary engagement in the roadmapping conversation [8, 9].

While there is significant research on the practical application of roadmapping in industry, fewer studies have focused on teaching roadmapping to students. Ulrich and Eppinger introduce technology and product roadmaps as part of product planning in their textbook, Product Design and Development [10], which is widely adopted in new product development courses. However, few academic programs [1] explicitly teach design roadmapping, and thus we know little about how a roadmapping process can best be embedded and taught in new product development courses [11]. Our research examines the implementation of design roadmapping within project-based New Product Development (NPD) courses at the University of California, Berkeley.

The research questions we address in this paper are:

- In what ways does the use of design roadmapping processes change the interactions on student NPD teams?
- What benefits do students see in applying design roadmapping to their projects?
- What are the pros and cons of using tangible versus online methods of teaching design roadmapping?

These questions draw upon literature on team communications and on the role that prototypes play in communicating.

[1] TU Delft offers a lecture on design roadmapping covering roadmapping theory, techniques and case studies in a master's level strategic product design program (http://studiegids.tudelft.nl/a101_displayCourse.do?course_id=41586)

1.1 Team Communication Challenges

Katzenbach and Smith [12] define a team as "a small number of people with complementary skills who are committed to a common purpose, set of performance goals, and approach for which they hold themselves mutually accountable". While interdisciplinary collaboration for innovation is highly encouraged [13], communication among members in a design team, group, or company is often quite fragile [14, 15, 16]. Kim et al. [17, 18] identify significant gaps of understanding between parties working on design within an organization in defining shared project goals and directions associated with roadmapping.

The invisible tension of a group of individuals to alter their thought world, compounds the inherent difficulty of creating shared frames and causes communication issues. The lack of shared language among human-centered design researchers, the product development team, and other stakeholders causes communication problems, which result in silos around these internal organization structures [13].

1.2 Tangible Tools to Enhance Communication

Observing and subsequently anchoring team efforts around the user experience help reduce the gap between designers and engineers [18, 19, 20]. Several communication related design methods help designers convey their ideas inside and outside the team [21, 22]. Communication can be tangible, virtual, or a mix of the two. Research artifacts such as prototypes play a crucial role in demonstrating an unexplored concept to other stakeholders within an organization and encourage better communication between researchers and practitioners in the HCI community [23].

2. RESEARCH DESIGN

2.1 Design Roadmapping Workshops

The notion of a "design roadmap" was introduced by Kim et al. [9, 17] and has since been refined through interactions with design roadmapping workshop participants from industry [18]. The design roadmap is a canvas that facilitates embedding user experience goals into the earliest stages of design and allows teams to envision how concepts can evolve over time to meet changing market conditions.

Building design roadmaps using tangible and digital tools

Visual aspects of roadmapping are often neglected, yet visualization can make a roadmapping activity more engaging and interactive [5]. We built tangible design roadmapping tools (Figure 1: top) of flexible wood materials with laser cutters in the Invention Lab at the University of California, Berkeley [24]. Each step of the design roadmapping process [17] was duplicated in the tangible design roadmapping tools. Parallel online design roadmapping tools (Figure 1: bottom) were also developed to compare participants' learning under different conditions.

Figure 1. DESIGN ROADMAPPING MATERIALS: TANGIBLE TOOLS (TOP) AND DIGITAL TOOLS (BOTTOM)

Both sets of templates include spaces to capture: key quotes, core needs, design principles, vision statement, three phases of product/service development. We provided the design roadmap framework and templates to the student teams in the early stage of their design work and then led the students through the process of completing the templates.

Workshop implementation

We conducted workshops with 234 students across a range of classes as shown in Table 1. One hundred and seven of the participants also completed an online survey for a response rate of 46%. We provided tangible design roadmaping platforms to half of the students and digital tools to the other half to study similarities and differences in the participants' answers and engagement levels by form factor.

Teams of 3-6 students worked on projects of their own choosing including: (1) sanitizing doorknobs, (2) cooking knife storage system, and (3) science education for children. We consulted with the course instructors regarding where to fit the design roadmapping workshops into their course schedules and agreed to include them after the first full cycle of the Human Centered Design (HCD) process (identifying customer needs, framing/reframing customer needs, concept generation, concept selection, prototyping and testing) [25] was completed (Figure 2). At this point, the student teams had their own customer data and had learned basic HCD concepts. The five steps of the design roadmapping process, summarized in Table 2**,** were modified to fit the course curriculum.

Table 1. BREAKDOWN OF WORKSHOP PARTICIPANTS FROM 2014-2017

	Number of students	Number of survey respondents	Response rate (%)
Graduate Capstone Team (Fall 2014)	7	7	100%
ME100 Team (Spring 2015)	4	4	100%
ME100 (Summer 2015)	40	39	97.5%
Graduate Capstone Team (Spring 2016)	5	4	100%
ME300 (Fall 2016)	58	32	55%
ME100 (Summer 2017)	42	4	9.5%[2]
ME300 (Fall 2017)	78	17	22%
TOTAL	**234**	**107**	**46%**

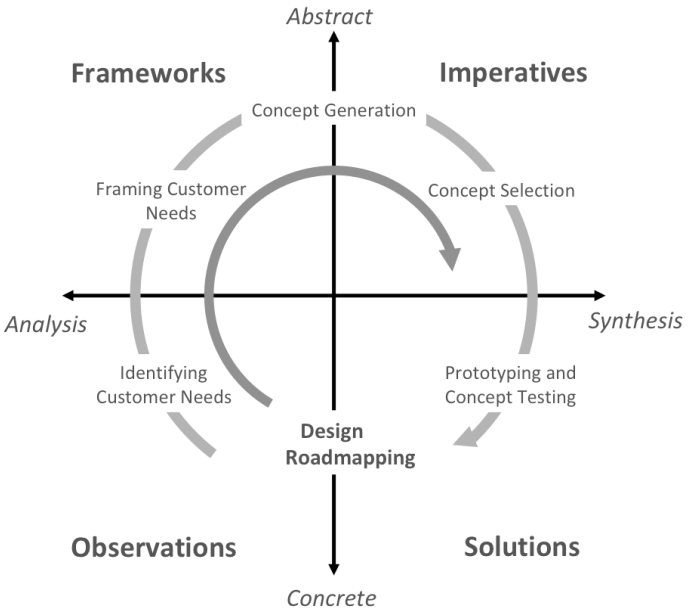

Figure 2. HUMAN-CENTERED DESIGN PROCESS WITH DESIGN ROADMAPPING INTERVENTION (MODIFIED FROM [25])

As the student teams had completed most of their design research and analysis they were able to begin step 1 with the data in hand and captured (up to) five representative quotes from their research in a design roadmap template. Step 3 was excluded in the workshops due to time constraints but was separately covered for those who signed up for an optional workshop. Step 4 was simplified as student teams worked on a single project.

[2] Note that we assume that the low response rate in this particular class is due to the later implementation of the workshop in the course curriculum where students busied themselves with prototyping and the final showcase preps.

Table 2. FIVE STEPS OF THE DESIGN ROADMAPPING PROCESS (MODIFIED FROM [17])

Step	Description	Source of Steps
1	Gather comprehensive data on users, users' experience, and trends	Conduct in-depth interviews, including expert interviews, and behavioral observations; identify unexplored needs and opportunity spaces for innovation; conduct comprehensive online surveys; review trend reports.
2	Extract core design principles from the user needs, experiences and trends	Identify common themes and insights and extract core design principles. Narrow user group focus. Find pain points. Create primary and secondary personas and use scenarios. Record key observations and data from these personas and use scenarios.
3	Gather an exhaustive list of technologies containing core feature sets of the design concept and prioritize them	Research existing technologies and functionalities. Brainstorm potential new features. Prioritize the technologies that best support core feature sets of the design concept. Select which technologies would be beneficial and useful for the target personas.
4	Map projects to design principles	Prioritize technologies based on design principles derived from themes and insights and examine how technologies can be applied to address opportunity spaces and pain points of target user groups. Rate projects relative to design principles.
5	Create Design Roadmap	Combine elements from user research and technology analysis to map out a plan that integrates human-centered solutions with targeted technologies of core feature sets for a design concept. Create a cohesive collective shared vision for the design team.

Half of the design teams received only online tools and the other half the tangible tools. Figure 3 provides images of two teams working with the different tools. Otherwise, both groups received the same direction, guidelines, and content.

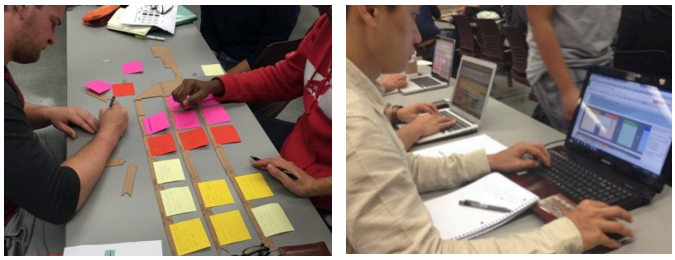

Figure 3. PHOTOS FROM DESIGN ROADMAPPING WORKSHOPS (SUMMER 2016)

As this was the first time the students had attempted design roadmapping, the background and concepts of design

roadmapping were introduced to the entire class before the workshops were launched. During the design roadmapping workshops, students were asked to capture each step of their work and submit their documentation to instructors at the end of the workshop. The final deliverables were collected in physical form from teams who worked with tangible design tools and digital form from those with digital design tools. The original physical deliverables were digitized for further investigation.

2.2 Online Surveys

A follow-up survey (Annex A) was administered to all 234 students who participated in the workshops. Administered online, it asked participants for specific comments and feedback on their workshop experience as well as overall satisfaction. One hundred and seven responses were collected and analysed; representative quotes are included in the data analysis and design recommendations sections of this paper.

3. DATA ANALYSIS AND RESULTS

3.1 Summary of Design Roadmapping Workshops

The analysis of data began by examining the outputs from the student teams. To provide an example of the kind of data collected, here is a description of Project Zest.

Sample design roadmap from the ME100 team Spring 2015

Project Zest: The Ultimate Kitchen Companion is a series of detachable sensors paired with a hands-free control mobile app to provide active recipe guidance and alerts to improve ability and enjoyment of cooking. Table 3 includes sample quotes from users and identifies core needs and design principles from these quotes based on research the design team did prior to the workshop[3]. Table 4 shows the concepts the team laid out for the short-, medium- and long-term for their project. Annex B includes more examples of design roadmaps created by student teams in the Summer 2015 class.

Table 3. PROJECT ZEST DESIGN ROADMAP - PART 1

Quotes	Core Needs	Design Principles
"You know what, it's always fun to watch a movie or listen to music while you cook."	Be entertained while cooking	Solution allows users to play their own entertainment (music, video) to make the cooking experience more fun
"My hands are always dirty, so I can't touch anything, can't change anything, or go online, and it's a pain."	Ability to operate even with dirty hands	Solution allows users to access, change their entertainment hands-free
"I consider myself a hobbyist in cooking, above average, but I still [mess] up a lot. That makes me want to cook to improve."	Learn to cook better	Solution encourages learning to cook better.
"I like cooking with people because it's fun and we can talk while cooking, so it's social."	Share experience	Solution allows users to share the experience of cooking, either virtually or physically
"I'll start off looking up a recipe...but then I'll just go off and do my own thing."	Become creative in cooking	Solution provides space for creativity in the cooking process

Table 4. PROJECT ZEST DESIGN ROADMAP - PART 2

Three Phases	Detail Design Roadmap in Each Phase
Phase 1 Solution allows users to play their own entertainment (music, video) to make the cooking experience more fun Solution allows users to access, change their entertainment hands-free	Enjoy music while cooking
	Follow instructions easily, step by step without confusion about which step user is on
Phase 2 Solution encourages learning to cook better Solution allows users to share the experience of cooking, either virtually or physically	Step-by-step instructions naturally incorporated in the activity so that users do not have to keep going back to device to check recipe
	Accurate description of each step, warns user about potential mistakes (e.g., too much of an ingredient)
	Prevents over/under-cooking food
	Prevents water overflowing
	Measures weight of ingredients conveniently without need for separate dishes
	Reminds user to stir food as needed
	Shares users' results (cooking experience and food) with others
Phase 3 Solution provides space for creativity in the cooking process such as adjusting recipes, creating new recipes, and trying new tastes	Interacts with users without having them check devices
	Leverages sensors in kitchen to retain awareness of what user is doing and supporting their activity
	Provides any necessary information on demand (amount of ingredients, weight, etc.)
	Provides a community that supports and encourages users to explore and try new tastes

Shifting focus from physical to intangible concept descriptions

We examined the concepts descriptions in the submitted design roadmap templates by the end of the workshop generated by the nine teams in the Summer 2015 class of 40 students (See Annex B). We coded the concept descriptions by form: physical, intangible, or a mix of the two. A *physical form*

[3] Note that the core needs and design principles are stated in the forms suggested by Ulrich and Eppinger, page 81-82 [10] and Kim et al. [17].

included, for example: "a fully functional accessory that is compatible with other general shapes of knives in the current market"; and an *intangible form* included "better cooking experience: with our product, more people would consider cooking an enjoyable experience. Thus, more people would be willing to cook at home".

The terminology students used in describing their concepts used more intangible forms and less physical forms as they moved from near-term to long-term concepts. Figure 5 shows how the percentage of references to intangible forms increased across the three phases of the design roadmap. This pattern was particularly true for students with mechanical engineering backgrounds. One hypothesis for this result is that engineering students tend to fixate around physical artifacts at the beginning of their design process. In the first phase of their design roadmaps, all nine teams described their concepts in a physical feature–based form (100%), none in an intangible form. In phase 2, three teams described their evolved concepts in non-physical ways such as experiences, services, users, or market contexts. In the third phase, 55% or four of nine teams used intangible formats.

While statistical significance cannot be assessed due to the small sample size, the increasing percentage of intangible formats being used suggests that design roadmapping positively influences design teams to be less fixated on hardware forms and to explore different forms of their concepts in planning over time. This further suggests a new pedagogical approach for training students to think more about exploring the intangible elements/experiences associated new product development.

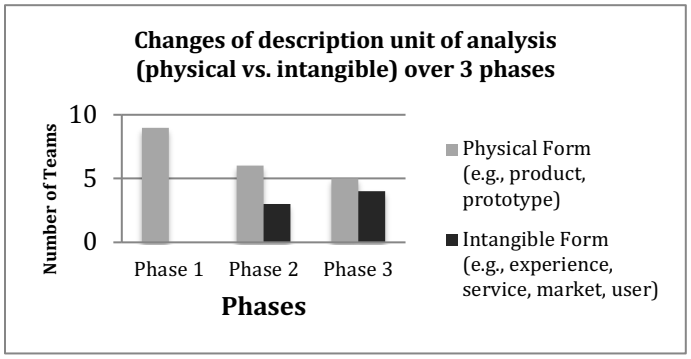

Figure 5. USE OF PHYSICAL VS. INTANGIBLE CONCEPT DESCRIPTIONS BY PHASE (SUMMER NPD COURSE 2015)

Comparison of tangible and digital design roadmapping tools

During the workshops, we observed more active physical engagement from the teams who were assigned tangible tools in comparison to the teams using digital tools. The tangible tools seemed to encourage more face-to-face communication and active team collaboration (moving pieces around, writing sticky notes, etc.). In contrast, the teams using digital tools were less interactive in person, but heavily relied on the computer for communication. For example, one six-member team using online tools didn't speak with one another during the entire workshop, but just stared at their laptops. The team members were all on the online chat messenger and were communicating about their project and the workshop through electronic media even though they were all physically present in the room.

Digital online tools, however, allowed the student teams to have constant access to their design roadmaps. Consequently, they produced better documentation of outcomes from the workshops thanks to increased accessibility to the datasets and prompt revisions regardless of their physical attendance or what digital devices (e.g., laptops or mobile devices) they might be using.

In addition, the teams with online digital tools provided richer descriptions of content in the online templates than those using the tangible tools. To analyze the richness of deliverables from the teams, we calculated the number of words in each cell (phase 1, phase 2, phase 3) and conducted paired t-tests to compare the difference between the groups using online tools versus those using physical tools for each phase. Student teams using online tools filled each phase of their design roadmaps with an average 28.6 words. In contrast, the student teams with tangible tools filled each phase with an average of 15.3 words. The difference is statistically significant at the 5% significance level (α=0.05, p-value=0.0013). The difference might be attributed to the easier accessibility to the online tools during and after the workshop, allowing more refinement of the workshop work.

3.2 Online Survey Results

Our online survey questions assessed overall satisfaction with the workshops. Participants were asked to rate how satisfied they were with the workshop on a five-point Likert scale from strongly agree to strongly disagree. This section presents the data captured as described in Table 1 from the 107 respondents to the survey over the years from 2014 to 2017. Figure 6 shows overall satisfaction with the workshops: 90% of survey participants responded that they were satisfied with the workshops; 10% were neutral or somewhat disagreed.

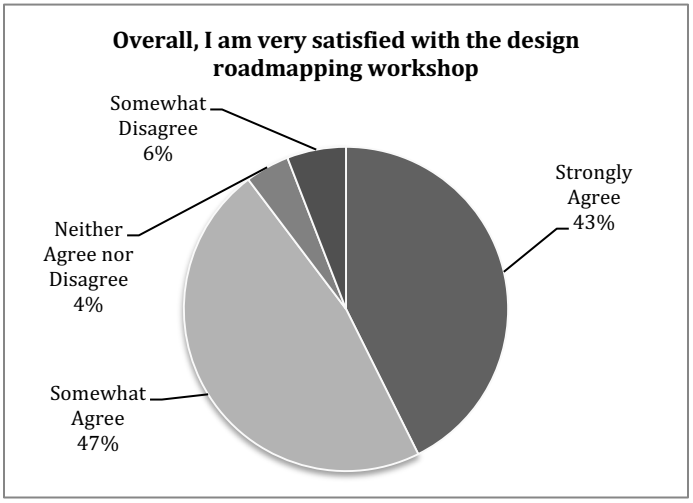

Figure 6. OVERALL SATISFACTION RATE OF THE DESIGN ROADMAPPING WORKSHOPS

Sixty-six students (excluding those from Summer 2015 who were not asked this question) were also asked what purpose they felt the workshops best served (Figure 7). Thirty-two of the 66 respondents (47%) reported that the most valuable contribution of design roadmapping was its usefulness in developing project goals/directions. That was followed by future prediction (25%), concept refinement (12%) and internal collaboration (10%).

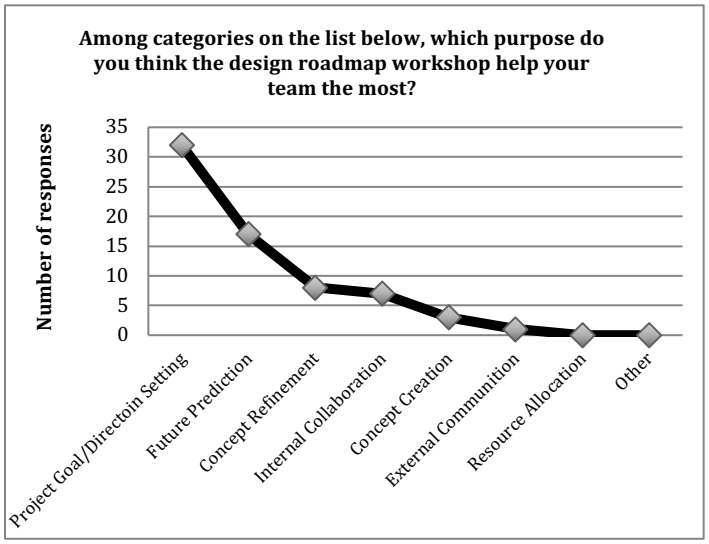

Figure 7. ONLINE SURVEY RESULTS FOR VALUE /USEFULNESS OF THE WORKSHOPS

These results sit in stark contrast to the benefits of product and technology roadmaps as cited in the literature: resource allocation, external communication, and stakeholder collaboration [5, 26]. Design roadmapping may have greater impact when it is added to the front-end design stage where the uncertainty around the project is highest.

Qualitative responses

We analyzed the qualitative online survey responses (questions 4-9 in Annex A) using grounded theory [27, 28]. Line-by-line coding analysis [29] was used to identify emerging patterns and insights from workshop participants. A total of 145 lines of code and 28 unique themes were generated, reviewed, and examined. The following summarizes the major themes.

Putting everyone on the same page

Many students said that the workshop helped get everyone in their team on the same page around: *longer-term goals and direction setting, and internal communication*.

> *"It helps us shape our goal, especially our long-term goal so that our project has more significant meaning. It helped our team make alignment."*
>
> *"We had to discuss a bit about the three phases since we weren't on the same page about our midterm and long-term goals, but the workshop was good for figuring that out."*
>
> *"It works well for reaching consensus and clarifies misunderstanding of the direction of the project. It helps us get a bit of a clean slate and get a plan for the future of the product."*
>
> *"Throughout the roadmapping, our team could reach consensus and clarify misunderstanding on the vision/direction of the project"*

Customer driven thinking than feature driven

Similarly, the design roadmapping process led to meaningful *consensus* within teams using a structured procedure for figuring out a team's vision *before* selecting product features and technologies for their project concept. As several respondents mentioned:

> *"It helped us A LOT in figuring out what direction our project is going in. We kept arguing over features and exactly what our product would do, and this workshop helped us focus on a vision to work around and see our customer's pain points."*
>
> *"We had trouble before agreeing on the main focus of our project and what features we wanted to implement in this iteration of the product, but after the workshop, it seems that agreeing will be a lot easier."*
>
> *"Once we wrapped our heads around the workshop, it became a lot easier to see what features we should focus on and where our concept should move in the future."*
>
> *"The [design roadmapping] workshop helped our team to extract all the information little by little from the project and project that onto the future paths."*

Apply a design roadmapping in an early NPD process

While further study as to where to insert design roadmapping into the NPD process is needed, our survey respondents suggest that the workshop would have had greater impact if it placed earlier in the project planning stage before the project's goal and direction were set:

> *"Perhaps doing the roadmap earlier in the design would help everyone understand the direction of our product -- there are many user needs competing for priority, but with the roadmap, we would all know which ones we are focusing on at which phase."*
>
> *"It would have been super helpful to have this earlier in our process (maybe when we were trying to see where to focus), or maybe doing small segments of the workshop throughout the semester to keep us focused. Either way, it was a huge benefit to us at this point in the semester regardless, so I'm extremely grateful."*

Visualizing the project in a design roadmap

Other participants described the benefit of design roadmapping as a tool to visualize future interactions of a product step by step over the planning horizon:

> *"It works well in the ability to visualize a conceptual project in future interactions instead of one huge project with one deadline."*
>
> *"I thought it was a very interesting way to visualize the project. It injects life into a product and gives the team a reference frame of what the project can become. We are not looking at just one product here. There are many facets to that product and many iterations before it becomes what we intend it to be in the first place."*

Challenges

While feedback on the workshops was generally positive, students also surfaced challenges. Here we summarize the main challenges identified:

(1) Clarifying terminology: Although the instructors provided clear definitions for the terminology used, students expressed some confusion as to how to interpret the terminology in the design roadmapping templates.

(2) Defining design principles: Some students said they had difficulty developing design principles for their projects. This step requires comprehensive research on market and user needs and time to digest that research to identify the main principles that should guide further development of the ideas. Students may not have had sufficient time to deeply explore needs, and thus get to useful design principles.

(3) Defining three (near-, mid-, along- term) phases: While developing three phases of a design helped teams to illustrate the evolution of their concept over time, some students had difficulty identifying them. The lack of experience of students as designers showed here, and the workshop design may need to be changed to accommodate less experienced designers.

4. RECOMMENDATIONS

Prototyping plays a crucial role in the design process. As an instantiation of a design concept, it generally happens relatively late in the design process when the team is converging around its ideas [30]. Our research suggests that integrating design concepts and prototypes earlier [31] during a design roadmapping exercise can be effective in enhancing team communication. In previous work, Oehlberg et al. (2009) found that drawings are helpful in conveying concept ideas within a team, facilitating teamwork and sharing [32]. Our results suggest use of different levels of prototypes representing more or less tangible concepts [30] would be valuable for the different phases of the development process, thus involving design-driven thinking across the near-, mid-, and long-term phases of the product evolution [17, 18]. While effective prototyping is valuable and may be a core competence that companies require [33], the prototypes illustrate only part of communicating the potential design experience.

Also needed is a better tool for students as a group (1) to align the project's direction and goals across the phases in the design roadmap and (2) to embody *anticipated desired user experiences* alongside the prototype concepts. The design roadmap provides a constructive tool for design teams to actively engage in possible future concepts based on both design and technology trends. Multidisciplinary collaboration has been widely adopted for new product development processes [34, 25]. However, fragility and dissonance across participating members still exist [13, 19, 35, 36]. Students examined in this research thought that they shared a common team vision but found that there were still significant gaps in how they defined and scoped their projects when they started the design roadmapping exercise. Adding the design roadmapping exercise as a part of NPD education could fill some of those gaps.

5. LIMITATIONS

The design roadmap is not a fixed canvas, but is meant to evolve over time [17, 18, 26]. The results and findings from this research are drawn from deliverables of student teams who built design roadmaps for the first time in their academic curriculum. Thus, this study only addresses the results that include their first attempt and does not examine revised versions which may have changed.

The difference in the number of words in each cell between online and physical tools do not necessarily reflect better quality in the resulting roadmaps. Further research could evaluate the quality of the roadmaps and concept generated could add insight around student learning and development.

Some students valued the presence of teaching staff as workshop coordinators/facilitators. The results might have been different if the workshops were conducted without the interactions from the instructor and teaching staff.

Due to limited resources, we only analyzed the data from the submitted deliverables from student teams. Although researchers were present in the room, conducting more direct observations of design roadmapping activities would provide a richer context around what student teams actually communicated throughout the process, possibly revealing new insights not caught by the content on the canvases.

6. CONCLUSION

In this study, we investigated how design teams apply the design roadmapping approach in their new product development process. We collected data from the deliverables from design roadmapping workshops and online surveys to understand how student teams use and learn from design roadmapping [9, 17, 18]. Our research, in conjunction with published results from previous studies, reveals that the addition of design roadmapping in new product development classes has beneficial impacts.

In this paper, we have shown that:

- Students use more intangible concept descriptions as they think out over a longer period than one semester, building upon the more tangible descriptions they use in the present.
- Students using tangible materials to build their maps interact more face-to-face; but are less complete in describing their concepts than students that use online tools.
- Students find design roadmapping useful for setting goals/direction, future predictions, concept refinement, and internal communication. Design roadmapping helps put members on the same page, makes the team more customer-driven, and the goals of the project more visual.

7. FUTURE RESEARCH

Further research should (1) clarify the terminology used in the design roadmap; (2) examine ways to help students better define design principles and articulate elements of the three phases on the design roadmap; (3) integrate other attributes such as desired experience levels and physical working prototypes to better help design teams exchange ideas and knowledge. The authors are also analysing the text and images on the design roadmaps to further understand patterns of use.

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ANNEX A

SAMPLE POST WORKSHOP ONLINE SURVEY QUESTIONNAIRES

1. (Background) Which group were you involved in?
2. Overall, I am very satisfied with the design roadmapping workshop.
    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree
    d. Somewhat disagree
    e. Strongly disagree
3. Among categories on the list below, which purpose do you think the Design Roadmap Workshop helped your team the most?
    a. Future prediction/plan
    b. Project goal/direction setting
    c. Concept creation
    d. Internal collaboration (as a team)
    e. External collaboration (besides your team)
    f. Resource allocation (human, time, materials, etc.)
    g. Other
4. What works well about the design roadmapping workshop?
5. What doesn't work well about the design roadmapping workshop?
6. Please describe the process used to capture user insights in your project before workshop?
7. Was there any conflict among your team members to collaborate during this workshop?
8. What was the biggest challenge during the design roadmapping workshop?
9. If you would like to share any additional comments, thoughts, or reflections on this workshop, please write them below.

ANNEX B

SAMPLE DESIGN ROADMAPS WITH CONCEPT EVOLUTIONS IN THREE PHASES

Group	Phase 1	Phase 2	Phase 3
Group 1 (Digital tool)	Create a working prototype to show the viability of a door-mounted UV Sanitation device.	Make the device retrofittable to different types of door knobs.	Develop a newer version of the product, which is smaller, cheaper, and uses less energy, while continuing to provide convenient and effective sanitization. Make it more compact. Make it a smart/programmable and secure lock.
Group 2 (Digital tool)	The device will be capable of disinfecting, and will be in as compact a form factor as is feasible while still allowing it to disinfect objects up to the size of a phone.	The device is available at an affordable price point, and will have a refined look, making it more attractive to the customer. It will feature revised internals to be more space efficient.	The device will be further refined to increase its desirability by making it more physically attractive, as well as by providing more variants to increase user choice. It may be adapted to purposes other than just small.
Group 3 (Digital tool)	A fully functional unit for most knives in the market: Making sure our product is compatible with the 3 general shapes of knives in the current market. Meanwhile, the product should stabilize and protect the knives.	A unit that can work well with most top kitchen drawers: Our product is able to work well with most kitchen drawers without causing damage.	Better Cooking Experience: With our product, more people would consider cooking an enjoyable experience. Thus more people would be willing to cook at home.
Group 4 (Digital tool)	Have a functional model that we can give to a student such that they can actually understand some new physics concept. The most fundamental basics of our prototype will be used to satisfy user needs and meet our vision statement (relatability, simplicity, interactivity).	The prototype will be further refined. A cleaner, more streamlined interface will further engage users. Hopefully we can implement a more innovative and intuitive UI design as well. More experiments will be added to further increase the size of the library. Possibly implement user-generated content with user moderation as well to allow user base and library to increase with one another.	Want to work to make a physical tool that will help implement our vision, although it may result in a slightly more expensive model.
Group 5 (Digital tool)	Improved housing search through preference filtering, advanced search capabilities, dynamic map and a proprietary matching algorithm.	Students are able to find and rent housing on our service Through secured payment gateways, verified users and verified listings.	To be the one-stop solution for everything related to housing, through seamless P2P transactions and interactions and scheduled payments.
Group 6 (Tangible set)	Functional prototype ready for longitudinal case study (2-4 month) decomposing design insight.	Marketing: Polished product including and FDA approval and journal paper.	Widespread, feedback driven iteration for MK 2. Expand target market and functionality.
Group 7 (Tangible set)	Make a fully functioning prototype that works as it should, but may not be easily manufacturable or made of the final material.	Develop a way to manufacture on a large scale, having settled on a material to use for the device.	Make a secondary version that gives a choice between accessorizing and portability.
Group 8 (Tangible set)	Have a completed workstation that has proper storage, great surface space useful utilities and can be showcased.	Gain feedback from many test trials and change the product according to feedback.	Analyze successes and pitfalls from first generation. Emphasize successful features and fix pitfalls.
Group 9 (Tangible set)	A basic, functional table that students will make a point to use on a regular basis.	More than just a desk. Physical attachments improve the work experience.	The desk is used by not just students, but everyone uses the desk in their daily lives as it is integrated into their work and personal lives.