A Human-Centered Design Tool Kit for STEM-Based Capstone Courses
General Design and Implementation in a Food Science Curriculum

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In fall 2019, a food science instructor partnered with the design center at a large Midwestern university to create a student activity tool kit for integrating the Human-Centered Design (HCD) approach into a science, technology, engineering, and mathematics (STEM)—based undergraduate capstone experience. This article shows how HCD can provide a student-centered approach to a capstone course and offers practical preparation, implementation, and evaluation materials for lectures, discussions, and laboratory sessions, all of which were used to guide instructors as they integrated HCD into a STEM capstone course. While a food product development course served as the model for other STEM capstone courses, the HCD approach is not discipline-specific; the activities and assessments conducted in this course can be applied across departments, from food science to bioengineering to chemistry and beyond.

Food Product Development is a final year capstone experience for the food science undergraduate concentration at a large, midwestern land-grant institution. The course uses a team-based format, providing students an opportunity to solve professional food science problems while developing novel food products. The course focuses on the principles of food product development, including concept development, formulation, manufacturing, packaging, pricing, safety, and marketing. Students are assigned to teams to ensure diversity within teams and distribute skills and knowledge continuity. Each week of the course includes two 50-minute scheduled lectures or discussions and a 3-hour laboratory session. Teams also participate in weekly team meetings to analyze and discuss collected data, research essential questions, and plan their subsequent laboratory sessions.

Prior to fall 2019, Food Product Development was taught using traditional product development approaches, including a melding of the classic Stage-Gate and Front-End Innovation models. However, in fall 2018, it became apparent that students’ interests in the product development process had shifted, and students indicated that they wanted a more contemporary food product development capstone experience. “Disruption” has recently become an important word in the food industry, commonly associated with start-up food and beverage companies that offer hyper-focused consumer products and emotional storylines. Support for disruption companies initially grew due to the distrust that millennials exhibited toward “Big Food” companies (Despain, 2016) and was further nurtured by stronger consumer connections to disruption companies’ unique product offerings. Start-ups were able to effectively “disrupt” the traditional “Big Food” supply because they embedded Human-Centered Design (HCD) into their innovation process. HCD is a problem-solving approach in which a group identifies the unmet need of a population in order to collaboratively develop solutions (Brown, 2008). HCD is derived from the blending of engineering methodologies, social sciences, and the liberal arts (Goldman et al., 2012). Using HCD, start-up companies gain a stronger understanding of their consumers’ wants, needs, and expectations based on a genuine human feedback cycle, not just reported trends.

The collaboration process
At the university where this study took place, there is a recently established design center whose mission is to practice, model, and teach design thinking, using HCD to re-imagine its campus, community, and collective world. The center identified the integration of HCD into on-campus courses as a key element of its mission (Shehab et al., 2021) in light
of research showing that engaging in HCD activities can help students develop human-centeredness, meta-cognitive, collaborative, experimental, communicative, and creative mindsets (Crismond & Adams, 2012; Culén & Gasparini, 2019; Goldman et al., 2012; Razzouk & Shute, 2012; Royalty, 2018). These mindsets match current employers’ demands and position students for effective engagement in future learning endeavors and active participation in today’s globally competitive world.

The food product development course was an excellent candidate for piloting HCD integration, due in part to its smaller class size and the openness of its teaching team (a faculty instructor [FI] and two graduate-level teaching assistants [TA]) to collaboration and change. TAs facilitated in-class activities and graded assignments. A design team that comprised a primary design assistant (DA), a secondary DA, and an assessment researcher supported the teaching team. The DAs’ position focused explicitly on helping guide projects through the HCD process alongside the course’s professor.

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The primary DA collaborated with the faculty instructor to develop the new instructional design, while the assessment researcher ensured the proper measurement of this new curriculum’s impact on students’ learning. The secondary DA was an additional facilitator when necessary (Lab 2: Synthesis and Lab 4: Concept Presentations). The design team was in class solely to present the new curriculum, while the primary DA joined weekly teaching team meetings and remained in close contact with the teaching team throughout the semester.

**Classroom management activities**

Managing the classroom experience is necessary for providing an effective, well-organized, student-centered capstone experience. The teaching team found the following course management approaches conducive to the implementation of HCD.

**Advance preparation**

Hitting the ground running was essential. To fill the first day with active learning, the teaching team distributed the syllabus, course schedule, and demographic survey in advance via email. This preparation ensured that the teaching team could use the first day for product development approaches instruction and engagement activities, which helped create a class culture of using time wisely and effectively.

**Team building and development**

Students were divided into teams of four or five, and each team member adopted one of five roles: leader, researcher, formulator, regulatory specialist, or document recorder. Teams participated in a 3-hour team-building and development session during the second laboratory session and were asked to create a team charter outlining their mission statement, role responsibilities, accountability, and expected efforts. These activities launched simultaneously with the HCD introduction and continued throughout the semester.

**“Bat(wo)man and Robin”**

The faculty instructor was the primary facilitator leading students through the HCD approach—essential for cultivating student buy-in to an unfamiliar problem-solving method. Instructor-class rapport must be established from the first day; having DAs leading activities from the start could undermine the instructor’s credibility. However, DA support for the instructor’s facilitation was necessary for the first year of implementation. DAs better understood the nuances of the approach and were able to assist in real-time alterations to the content in response to time limitations and other unforeseen challenges. This was colloqui-ally referred to as the “Bat(wo)man and Robin” approach, as the faculty instructor was the primary driver of content and DAs served as support. In this first year of collaboration, the DAs often coached the instructor and TAs through activities, while the instructor remained the lead student-facing facilitator.

**Teaching with HCD**

When teachers teach with HCD, they think and act like designers, actively practicing empathy by communicating with students to better understand their backgrounds, learning preferences, and learning difficulties (Henriksen & Richardson, 2017). They utilize these learnings to design instruction and materials, implement new instruction, and iterate upon activities based on student feedback; this approach allows instructors to adapt throughout the semester, freeing them from overly structured activities. However, instructors must be open to uncertainty and failure during this process. Teaching with HCD can engage students cognitively and emotionally with the content, which can then result in higher motivation and performance (Henriksen & Richardson, 2017). Students described seeing the teaching team “practice what they preach” as a factor in their engagement and overall enjoyment of the course. The FI taught with HCD by implementing early (and frequent) student team check-ins and pulse checks with the instructional team.

**HCD learning activities**

To teach about and through HCD (Shehab, 2020), the design and teaching teams co-designed and implemented activities that give students opportunities to learn and practice HCD processes and to acquire and apply the concepts of a discipline in order to make justified design decisions. The following is a detailed description of these activities and their implementation in the course.
Product development introduction

Class 1 introduced students to various product development approaches, highlighting the strengths and weaknesses of each approach and discussing the various businesses that used the approaches. Students were then instructed that the HCD approach would be used throughout the semester.

Students needed to hear early and often that HCD is not a linear approach. Breaking down the concepts of divergent and convergent thinking helped students know when to balance creativity and generativity with being more critical and specific. We introduced the HCD taxonomy (Figure 1), connecting each activity to a space in the approach. Each day’s lesson was centered on the appropriate space of the approach, continuously reinforcing those connections.

Chopped design sprint as a low-risk introduction to HCD

The first lab of the semester was a short design sprint in the style of the popular television show Chopped. Teams interviewed first-year students about their relationship with food, using the answers as inspiration to formulate a dish using three key ingredients. This preliminary run-through of the process served as a low-risk interview and synthesis experience (two practices within the HCD approach that were less familiar to students) and allowed teams to collaborate before selecting formal roles (e.g., leader, researcher, formulator). The competition element incentivized technical challenge selection; teams that were more successful in the Chopped exercises got to pick first from a list of approved technical challenges for their semester project. When the lab concluded, each team selected their technical challenge (e.g., “excellent source of plant-based protein,” “ketogenic-diet friendly,” etc.), which served as their foundation as they moved through the HCD approach to developing a novel food product.

The Understand space: Interviews and empathy

How do I interview? lesson

Class 2 started with students sitting with their teams and the instructor explaining the difference between teams and groups and their respective projects. Per Katzenbach and Smith (2015), groups can be large, may share interests but may not share goals, can perform and be held accountable through individual contributions, are made up of members that possess random skill sets, and act in a cooperative or coordinated manner. Teams, however, are small (between three and five members), share common goals, require members to perform interdependently with deep knowledge and mutual accountability to each other, include members who possess complementary skill sets, and act collaboratively.

Students began by exploring their assumptions going into their projects. Students were asked to consider the question “What are the components to a nutritionally adequate meal?” Then, they provided an example to challenge common assumptions (e.g., because many students assume such a meal is composed of multiple foods, we present Soylent as an example of a nutritionally adequate meal composed of a single food). This step showed the importance of documenting individual perceptions of a challenge, which clears the path for students to think outside their own perceptions. Later, discussion of “extreme users”—stakeholders with atypical experiences (e.g., someone with a severe food allergy)—challenged students to think beyond their initial assumptions.

FIGURE 1

The human-centered design taxonomy.

Source. Lawrence et al. (2021).
of who a consumer might be.

It was essential to refer back to the HCD taxonomy (Figure 1) to tie the content of the lesson back to the particular space of focus. This step was completed for every lesson, driving home the importance of the taxonomy as a framework for understanding the HCD approach.

An opportunity for very basic interview practice was provided in this class, with additional practice opportunities built into the first lab class (the Chopped design sprint mentioned earlier). The formal interview activity was assigned after the first lab. During Class 3, TAs provided early informal feedback on the first 3 (of 10) interviews, so that the teaching staff could check in with teams before the due date.

**In-context observation: Supermarket exploration**

During Class 4, students went to the supermarket to observe consumer behavior and reflect on competing products. The collected observations were a valuable supplement to the interviews the teams had conducted. An accompanying worksheet provided guidance; however, students did not independently review the worksheet before arriving at the supermarket and were thus underprepared to optimize the assigned tasks. Incorporating time during a class session before the designated supermarket day would enhance data collection during the exploration.

**48-hour diet empathy exercise**

In an effort to further embed empathy into the product development experience, student team members followed a 48-hour modified diet or food waste collection activity aligned with the team’s selected technical challenge. During the concept presentations, teams presented on nutritional, organoleptic, product and package design, social- and community-oriented, and accessibility strengths and weaknesses they identified relative to their technical challenge. Teams also indicated how they would create a product that could provide benefits to their consumer, emphasizing strengths and minimizing weaknesses experienced with their technical challenge. Thanks to this experience, teams gained consumer insights that were not previously accessible in the course.

**The Synthesize space: “How might we …?” questions and personas**

A guided lab led teams through the most abstract phase of the HCD approach: synthesis. It was essential to have both the primary and secondary DAs help facilitate the day’s lesson. The primary outcomes of the synthesis activities were “How might we …?” (HMW) questions and personas. HMW questions were formed via insights gathered through the observations and interviews, and the questions articulated five different design opportunities to facilitate brainstorming. Teams developed personas to demonstrate the different behavioral segments found in their research. HMWs and personas were essential reference points for brainstorming and proved useful later as teams struggled during their prototyping.

Students initially got caught up in the color coding of sticky notes and structuring layouts while recapping their interviews and observations. Within 20 minutes, teams progressed into properly focused downloading. Moving tables together gave students more room and helped accelerate the
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Class 6 allowed teams to provide
feedback to others on early personas.
This process was useful in challenging
students to present ideas for feedback
early. It was also emphasized that
these personas—and frameworks in
general—should illustrate an insight.
The next portion of the lesson showed
how to frame insights as design op-
portunities for ideation through the
use of HMW questions. Teams were
each assigned to create five HMWs.
Each team then met with the teaching
team for feedback on their HMWs.
These sessions allowed the instructor
to use content-specific knowledge to
guide student teams toward achiev-
able outcomes and to frame ideation
properly.

The ideate space

Ideation took place during Lab 3.
Music was played during activities,
filling the room with energy. It was
essential to have a highly structured
brainstorming session and not a free-
ly generative session. Timed activi-
ties with expectations for outcomes
(e.g., number of ideas generated in a
certain time) set the parameters for
creativity. The teams had an intuitive
understanding of the next steps, with
some groups naturally moving on
to the next stage before instructions
were given. This progress was not
discouraged, but we strove to main-
tain a tempo that kept groups work-
ing at the same relative pace.

This lab was structured to ensure
teams ended with three concepts re-
quiring feedback. Most teams had a
fairly clear idea of their top concept
by the end of this session. Therefore,
it was doubly important to have them
bring several ideas for evaluation, as
this prevented them from getting too
attached to a single concept.

Concept presentations: The value of storytelling

Presentations created a sense of ac-
countability that students met with
enthusiasm. Several groups went
beyond scoping out the feasibility
of their concept proposals, with one
team even reaching out independ-
ently to coffee farms in Hawaii to dis-
cuss sourcing coffee fruits for their
products. This major presentation
midway through the semester was
a critical checkpoint for teams, pro-
viding them accountability as well as
an opportunity for focused feedback
on their project before any technical
prototyping began.

Food science content
learning activities

The insights, themes, and HMW
questions that evolved throughout
the first 5 weeks of the course served
as the essential foundation during
the iterative prototyping stage that
was the emphasis for the remaining
11 weeks of the semester. Teams op-
timized their concepts by applying
previously learned food science fun-
damentals—including food chemis-
try, food microbiology, food analy-
sis, quality assurance, food safety,
food processing, and sensory evalu-
ation (Wang & Bohn, 2018)—while
purposely returning to their insights,
HMWs, and personas for human-
centered context. By encouraging
an HCD approach to the prototyping
weeks of the course, teams were able
to consistently recognize the posi-
tive impact their novel product could
have on their target population. This
understanding was especially benefi-
cial when, during prototyping, teams
started to drift away from their origi-
nal concept or began questioning the
purpose or significance of their in-
novation. Collaboratively, the teams
and the teaching staff were able to
meet and reflect on the insights from
the first 5 weeks, often rejuvenating
the teams and reminding them why
they decided to create their novel
food product.

Reflecting on the insights obtained
during the first 5 weeks became
especially important when teams
were optimizing the quality of their
innovations. During the quality as-
surance weeks, teams often reminded
themselves of their personas or
reflected on what they learned from
their insights and HMW questions
to select consumer-appreciated in-
gredients, optimize formulations, set
quality specifications, and create ap-
pealing (and appropriately regulated)
package and label designs. The first 5
weeks were also highlighted through
a proposed social media advertising
campaign and final product pitch
assignments; the insights from these
weeks enabled the teams to tell inspir-
ing and often poignant stories con-
necting consumers to their products.

Conclusion

The activities discussed in this ar-
ticle can be used when incorporat-
ing HCD into a university- or col-
lege-level STEM capstone course.
The tool kit developed through col-
laboration between a food science
course and a design center integrates
elements of teaching with, about,
and through HCD. Additionally, we
found key classroom management
activities (e.g., teaching with HCD)
to foster success among teams uti-
izing HCD to develop novel food
product concepts. Throughout this
collaboration, it was essential to
have assessment at the forefront of

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the approach. Incorporating rubrics for key activities and working with a learning sciences mindset meant the impact of HCD on students’ learning was measurable and significant (Shehab & Guo, 2021). We believe the success of this collaboration can be transferred to other capstone courses in STEM and encourage other instructors to try this in their classrooms. (To access any of the materials [such as lesson plans, lectures, etc.] used in this pilot course, please reach out to the authors at designcenter@illinois.edu.)

Acknowledgment
In spring, 2019, the primary DA and the FI were connected through the design center. Upon meeting, they began developing a strategic plan for the development of a universal instructional toolbox for the incorporation of HCD into a STEM-based final year capstone experience. Collectively, the primary DA and the FI submitted a proposal for the university’s provost office’s grant program, and they were awarded $7,500 in funding to pursue this initiative.

References


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