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Edible Entertainment: Taste Diversity in Additive Manufacturing for Authentic Digital Food Design Solutions

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1. Introduction

Entertainment as a communication and experimental platform can be effectively applied for introducing students to social issues related to food equity, nutrition, and security in classroom learning environments. These issues are characterized by the lack of consistent access to enough food for an active, healthy life. Educational projects at the intersection of food and entertainment has the potential to raise awareness about social issues and encourage students to creatively think about innovative solutions using digital entertainment tools and human-centered design methodologies. This paper presents the results of our exploration at the intersection of food and entertainment by introducing the concept of edible entertainment to students in a graduate level course in a university setting. The term 'edible entertainment' is an open concept for exploration that started off during one of the conversations between the authors of this paper. The authors' expertise in the areas of additive manufacturing, 3D-food printing and entertainment graphics led to a discussion on the potential overlap between the two fields. This discussion led to the design of a student project that will initiate conversations at the nexus of food, culture, and entertainment.

This topic is of value to students for various reasons including awareness of food security as a responsible citizen, understanding, and applying food as a form of social experience and entertainment to generate awareness as well as exploring the application of modern technologies such as 3D printing at the point of need as a mean for a potential solution for food insecurity [1]. Several study reports focusing on college students reported that about 20-40% of the students face food insecurity across the US college campuses [2]–[6]. The main goal of this social experimentation is to explore the opportunity at the intersection of food & entertainment for awareness of food equity, security, safety issues, explore new innovations & knowledge retention among students. The educational goals of the 12-week project was to:

- Develop an awareness on the topic of food inequity issues, nutrition security and health among students specializing in computer graphics technology.
- Co-create authentic food experiences through personal, cultural, and social narratives.
- Prototype entertaining digital food design solutions to address food equity issues.

Our research objectives in designing this interdisciplinary project is to encourage non-traditional solutions in project-based educational methods. Taste diversity is the affection of various cultures to respective foods, and their permutations and combination, especially as we experience the fusion of cultures and related food combinations in the globalized world. We created a platform for students to identify taste diversity parameters in additive food manufacturing

processes [7] and to develop socio-culturally validated authenticity in digital food design solutions that addresses food equity issues.

Student reports were evaluated based on the feasibility of the prototype in improving taste diversity in additive food manufacturing process, and the application of inclusive play interactions in digital food experience design to enhance the entertaining value of the product. The impact of this interdisciplinary project on the motivation, commitment, and success levels of students were evaluated using an end of semester survey and instructor feedback questionnaire with self-reporting of students' learning. Data was collected in the form of students' final reports that included conceptual sketches of the prototypes, user journey maps, self-reporting through surveys, observations in class discussions, peer critiques, final presentation, and online discussion threads. The data analysis results show that students were excited about working in this project and it helped them understand the topic of food security, nutrition, and safety. Student feedback also provided guidelines for project design and future work in this direction. Overall, the project met the learning outcomes and had a positive student engagement and project rating.

2. Details of the Class Project

Class Framework

The course 'Design Futures' (DF) for entertainment graphics practices is a graduate level special topics course offered to Master of Science and PhD degree students specializing in computer graphics technology studies. The degree program offers courses in technical graphics programming, game development and 3D animation classes to prepare students for the entertainment graphics industry that includes video game development, virtual simulations, mixed reality application development and animation. One of the main objectives of this special topics course offered in Fall 2022, was to challenge students to critically look at their own computer graphics practices and speculate future scenarios [8], [9] for digital entertainment - situated in projected futures impacted by various social, economic, and environmental scenarios. Students were introduced to design research methodologies and speculative tools to prototype the future of entertainment practices and design strategies to create human-centric entertainment content. Students had backgrounds in programming, game development, experience design and science.

The course structure included lectures on speculative design, design fiction, sandbox activities to prototype alternate futures, case studies, presentations, and workshop sessions. The class met once a week for three hours and had ten students (nine international students coming from various countries) enrolled in the class.

The projects integrated with this course required a knowledge of real-world social issues that can lead to digital innovation through entertainment graphics as a communicative tool for effective dissemination and practice. The course instructor (from computer graphics technology department) collaborated with a senior faculty researcher from the mechanical engineering department who specializes in the area of additive manufacturing. The faculty researchers had regular biweekly meetings during Summer 2022 (before the course was offered) to identify opportunities at the intersection of additive manufacturing, food and entertainment that can lead to pedagogical learning experiences for students. The result of this discussion led to this project on edible entertainment.

Project Details and Execution

This project contributed 20% of the overall grades of the course. The project is designed for students to work individually on the solutions, discuss and critique as a class and was spread across 12 weeks; each week's activity was aligned with the corresponding weekly course learning objective provided in Table 1 below.

Table 1: Weekly learning outcomes

Week	Learning Outcome
1	Understand the need for design approaches in entertainment industry practices
2	Explain the entertainment theories that inform effective production practices
3	Observe traditional entertainment practices
4	Apply speculate design research methods
5	Compare experiences in the physical-digital continuum
6	Apply design fiction research methods
7	Identify the medium and material for design
8	Classify sensory entertainment design
9	Discover sensory suspended entertainment modes
10	Recognize emergent qualities of entertainment design
11	Design future-oriented professional roles
12	Design future-oriented interactions based on critical scenarios

A major challenge in designing this project was - how to introduce socially relevant topics around food security, nutrition and equity to computer graphics students specializing in entertainment development, who have never had these discussions in class. USDA defines food insecurity as "Limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" [1]. To overcome

this challenge, the collaborators (authors of this paper) introduced weekly design activities related to the project and announced the objectives of the project and its final deliverables closer to the end of the project timeline. This way, students were able to organically participate in the class activities and corresponding online discussion threads without trying to objectively solve the issue in one attempt. This approach also made students absorb the various dimensions of the problem, before relating to their own practices within games and animated media.

Table 2. provides the details of the weekly project goals and the corresponding design activities conducted in class and/or offline by students.

Table 2: Project timeline and weekly activities

Week	Project Schedule	Notes
1	Project: Introduction to Edible Entertainment Project	Food - emotions - narrative mapping
2	Project: Personal Narratives	Short reflection of personal narrative that explains mapping
3	Project: Medium	Explore the physical and digital material involved in the mapping
4	Project: Methodology	Identify, frame an experience, and develop a workflow
5	Project: Design tools & material	Identify tools and material needed to re-create experience
6	Project: Prototype	Prototype a probe that embodies the food experience
7	Project: Prototype	Prototype a probe that embodies the food experience
8	Project: User study	Conduct pilot studies with users' interaction with food experience probe
9	Project: Refinement	Refine probe based on user data
10	Project: Presentation & Peer Critique	Present probe in class
11	Work Week	Work Week
12	Project: Submission	Submit the report

In this section, we provide more details on some of the highlights from the weekly activities. The weekly activities can be categorized as:

- Class activities and online discussion threads that explore personal experiences related to food, play and social relevance.
- Invited lectures focusing on additive manufacturing, 3D food printing and role of digital design in taste diversity and food equity.
- Scaffolded design phases of ideation, problem framing, prototyping, testing and refinement.

Week 1 started with an ice-breaker session on 'food – emotions – narrative mapping'. An image of a tomato was shown to students followed by a series of questions on:

- Can you identify the emotions that arose by seeing the image of a tomato?
- Why did you feel the way you did?
- What was the source of this emotion?
- Can you retell the narrative that triggered this emotion?

Week 2 and 3 class discussions led to a deep dive into student's personal narratives and the physical/digital medium involved with the food-emotion-narrative mapping. Week 3 discussions were accompanied by an online discussion thread that asked students to share their personal food experience (min 100 words) through a structured thought process described below:

- An edible material that comes to your mind.
- A food item made from this edible material.
- An emotion that arises out of this food item.
- Map the food - emotion pair to a personal narrative from your own life experience.
- Can you travel to this time of your personal life and explain the other sensory elements that contributed to this food - emotional experience?
- What do you infer from this exercise?

Week 4 shifted to an exploration of play potential related to food. Students were asked to respond to the following prompt in the online discussion thread:

- Identify three key play potentials in the food item that you represented in the class activity.

Week 3 and 4 also had invited lectures by researchers from the mechanical engineering department. Week 3 lecture topic covered essential discussions on food security, nutrition, and safety. Week 4 lecture discussed concepts of additive manufacturing and 3D food printing technologies. The lecture also included videos that demonstrated the potential of 3D food printing. Food printing is an emerging area of research for food additive manufacturing [10]. Video references of 3D food printing techniques that uses food in the form of slurry that can be extruded were shown during the lectures. The following figure provides a graphical representation of the 3D food printing developments in the recent years.

Figure 1: 3D printed pancakes – Recent advancements in 3D food printing [11]

This introduction led to further class discussion on topics of human interaction with food and the role of digital design in taste diversity and food equity. After several weeks of discussions, readings, lectures, and class activities the project objectives, design process and deliverables were uploaded on the online student learning portal. The main objectives of the project was laid out as:

- Co-create authentic food experiences through personal, cultural, and social narratives.
- Prototype entertaining digital food design solutions to address the issue of food equity, security, and nutrition.

The criteria for evaluating the projects was based on:

- Feasibility of prototype in improving taste diversity in additive food manufacturing process.
- Application of inclusive play interactions in digital food experience design to enhance the entertaining value of the product.

The project specifications supported students to frame the problem, contextualize the problem based on personal reflection and classroom discussions, and find digital solutions. Students followed the following steps through the design phase of the project:

- Start with the personal narrative developed through reflections from the food - emotion mapping activity.
- Explore physical and digital materials involved in the mapping.
- Frame a digital food experience based on the above two activities - situating it in a cultural & social context in a near future scenario.
- Identify tools, material, and processes for the experience creation.
- Prototype a digital food probe that embodies the food experience.
- Collect feedback from peers based on the evaluation metrics and refining the prototype.

The expected deliverables for this project was a pdf file with detailed documentation of the design activities with sketches, observation data, reflections, visual and textual material - with a word count of 750 - 1000 words.

3. Results and Discussion

Prototype Evaluation & Instructor Feedback

The expected outcome of this class project were to:

- Develop an understanding of food equity issues and the importance of additive manufacturing technologies (3D printing) to address the problem.
- Develop prototypes of digital food design solutions that embody diverse narratives and edible taste interactions.
- Identify ways to apply this digital prototype to resolve real-world food equity and nutrition security problems.

The evaluation criteria set for the project reports helped measure whether the learning objectives/expected outcome of the class project were met or not. Student project reports, online discussion threads and reflections show that the learning objectives were successfully met in this class project. Online discussion threads showed positive student engagement and deep reflections of student's own food interactions and an urge to develop diverse narratives around the topic of food. Student inputs in these threads were well-aligned with class discussions and had follow-up reflections from questions raised during class discussions and the guest lectures.

Students took the initiative to conduct secondary research on the topic of food security, safety, nutrition, and equity. The topic of additive manufacturing and 3D food printing are new to students. However, within a short period of time, students were able to acquire details about state-of-the-art technologies in this field, collect online statistics related to food safety issues and present them in class. A textual analysis of the final solutions provided by students provide evidence of successful learning outcomes that meet the project goals as explained below:

- Understand the issue: A common pattern in the submissions was that students were motivated to explore the issue from a personal experience standpoint. This could probably be due to the sequence of activities introduced in class. Only three reports out of the ten made references to research work on food equity and related trends. However, all the solutions were directed towards the larger population with detailed explanations on how their prototypes could address food-related issues and ways to measure its impact. These refinements partly come from the peer critique during class presentation of work-in-progress ideas.
- Develop solutions that incorporate taste diversity: All student reports had a well-articulated narrative on personal food experiences and its influence in designing their digital food solution. Students referred to social events and family gatherings that reminded them of certain forms of food. Prototypes in the form of mixed reality experiences, mobile application development and 3D food printing had elements of these personal narratives. Students also measured the impact of their prototypes through these personal narrative lenses for taste diversity.
- Identify solutions and apply them to real-world problems: The solutions were in the form of conceptual sketches and detailed user journey maps with reference images for cultural backgrounds and context. The importance given to personal narratives and food interaction experiences resulted in diverse solutions and problem-framing approaches by students.

Common feedback provided by students during the class presentation is that they would prefer to work for longer durations on this project. Students showed interest in implementing their prototypes as part of the class project and measure the prototype's impact in addressing food equity and taste diversity issues within the additive manufacturing space. Nonetheless, all students were fully engaged in the whole process. The title 'edible entertainment' was intriguing to students and the project enabled them to think beyond their own disciplines.

Students feedback

The impact of this interdisciplinary project on the motivation, commitment, and success levels of students were further measured using an end of semester student survey. Table 3 shows the survey questions provided to students.

Table 3: End-of-Semester Student Survey on Project

#	Question
1	Food equity, security & nutrition: What do these topics mean to you and how do you interpret the problem?
2	What is your perspective on using play and digital entertainment to find innovative solutions in the problem space?
3	What excited you about the concept of edible entertainment? Did the project meet your expectations and why so?
4	Did the project structure and design process help you achieve the objective of: 1. Co-creating authentic experiences 2. Addressing food equity issues/taste diversity in additive manufacturing
5	What are the skills you learnt in this project that you plan to apply in your own professional practice and/or discipline of study?
6	Additional Feedback

A qualitative analysis of the survey responses led to the following discussion:

Students were able to define, differentiate and appreciate the concepts of food equity, safety, and nutrition. They acknowledged the existence of these problems in their surroundings and expressed surprise over the intensity and widespread nature of the problem - “Coming from Nepal, I always thought the issues related to food equity, security and nutrition were confined to countries like ours, so I was very surprised to know that it is a very big problem even in countries like the US. It is one of the biggest issues facing our world today and the utmost should be done to solve them” (response #3). Students were also able to interpret potential problem areas that require future work - “It is essential to look for sustainable methods of food production. One also needs innovative food distribution methods to reduce the inequal availability of food all over the world” (response #2). Students see play and digital entertainment as a good way to create awareness about these issues. However, they highlighted the need for government policies and interventions as major sources for change and entertainment as an add-on in the solution space. There is an agreement that the concept of play and entertainment provide us with a lot more vision towards new and innovative ways of creating food solutions.

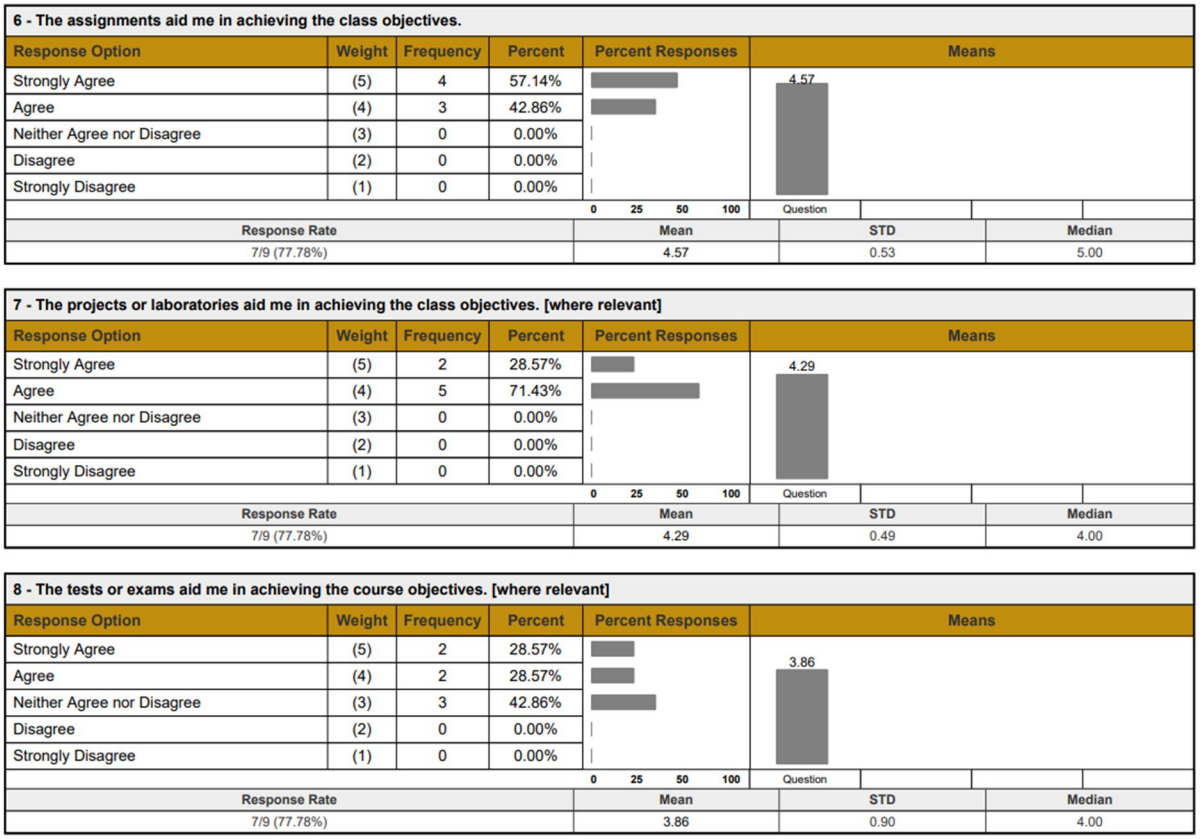
The concept of edible entertainment and the question of whether the project meets student experiences had some interesting responses. Students saw this as a unique project as it combined the ideas of using future technologies to create entertainment solutions to improve the food equity problem. The idea of combining creativity and cultural aspects was exciting. It gave students an opportunity to understand how food is made and that met their expectations. Further responses provided feedback for future work - “The experience of enjoying good food is already a form of entertainment. But using it to tackle the problems of food scarcity is an innovative

aspect. However, all the examples shown seemed to be targeted towards well-off people as a form of exotic dining experiences. One can however use some of these features to create awareness and normalize more sustainable food products in the market such as cultured meat products. The promotion and normalization of alternative food sources can be done" (response #2). "Personally, attacking both problems of food equity and edible entertainment in the same project was a bit difficult. While the food equity aspect did narrow the problem space, I feel that it limited the resulting solutions. If it focused more on the entertainment aspect, I might have enjoyed it a bit more" (#response #6).

All students were satisfied with the project outcomes. Some students additionally commented that – "learnt a lot about additive manufacturing in class and it was very fun and interesting to see how my classmates used this concept to come up with different ideas to solve food equity issues/taste diversity" (response #3). "Due to who the users/stakeholders would be in this problem space, I feel that this project was lacking in co-creation. Some of the solutions that were discussed in class had potential to address food equity issues, but some of them strayed from this and focused more on sustainability aspects more" (response #6). Overall, the project helped students come up with innovative solutions for food related issues, setup a workflow for digital solutions and more - "I have prototyped before in 2D (app layouts), but this project required me to think in 3D, since food is a tangible object" (response #4).

Student Project Examples: One student project investigated a gamified recipe wheel that involved big data analysis of over supplied food ingredients in the local market. This solution targeted the issue of food inequity and food waste. Another example is the curry bar processor that used 3D food printing technology to prepare curries from different geographic regions for people to prepare, taste and appreciate food diversity using advanced 3D printing technology. The portable solution could also eliminate the use of tableware and containers. Kitchen gardening – a concept for easy access to healthy, nutritious food is yet another example of designing futuristic automated greenhouse systems to grow various vegetables, fruits and herbs that are not otherwise accessible in a specific geographic area.

Additionally, students' feedback on the overall course and course objectives was collected through the semester-end course evaluations and students shared positive responses for the overall objectives of the class and class projects as suggested by the statistics presented in Figure 2 below:



6 - The assignments aid me in achieving the class objectives.

Response Option	Weight	Frequency	Percent	Percent Responses	Means
Strongly Agree	(5)	4	57.14%		4.57
Agree	(4)	3	42.86%		
Neither Agree nor Disagree	(3)	0	0.00%		
Disagree	(2)	0	0.00%		
Strongly Disagree	(1)	0	0.00%		
				0 25 50 100	Question

Response Rate	Mean	STD	Median
7/9 (77.78%)	4.57	0.53	5.00

7 - The projects or laboratories aid me in achieving the class objectives. [where relevant]

Response Option	Weight	Frequency	Percent	Percent Responses	Means
Strongly Agree	(5)	2	28.57%		4.29
Agree	(4)	5	71.43%		
Neither Agree nor Disagree	(3)	0	0.00%		
Disagree	(2)	0	0.00%		
Strongly Disagree	(1)	0	0.00%		
				0 25 50 100	Question

Response Rate	Mean	STD	Median
7/9 (77.78%)	4.29	0.49	4.00

8 - The tests or exams aid me in achieving the course objectives. [where relevant]

Response Option	Weight	Frequency	Percent	Percent Responses	Means
Strongly Agree	(5)	2	28.57%		3.86
Agree	(4)	2	28.57%		
Neither Agree nor Disagree	(3)	3	42.86%		
Disagree	(2)	0	0.00%		
Strongly Disagree	(1)	0	0.00%		
				0 25 50 100	Question

Response Rate	Mean	STD	Median
7/9 (77.78%)	3.86	0.90	4.00

Figure 2: Project and assignment-related questions from the course evaluation results.

4. Summary and Conclusion

This project was a first step in our collaborative work at the intersection of food and entertainment. Students appreciated the concepts introduced in the course. A major takeaway from the student responses is to spend more time on building functional prototypes and co-create these solutions with the target audience. This version of the project had virtual introductions to additive manufacturing and 3D printing concepts. Hands-on experience with these technologies is anticipated in future work. This will require further collaborations between the different disciplines involved in this project. Future iterations of this project will include small focus groups with students, to collect critical feedback for curriculum development. The topics will also be narrowed down to focus on one specific issue – e.g. nutritional value of 3D printed food. The projects will also require active participation from community stakeholders who are directly impacted by the solutions developed by students in the classroom.

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