INTEGRATING DESIGN-BASED PRACTICES AND DIGITAL TECHNOLOGY TOOLS IN APPLIED SCIENCES: A CASE OF GASTRONOMY EDUCATION

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To my family & my friends their support and encouragement...

DECLARATION OF ORIGINALITY

I hereby declare that I am the sole author of this thesis and that this is the true copy of my thesis, including the final revisions, approved by my thesis committee. All data and information have been obtained, produced, and presented in accordance with the rules of research ethics and principles of academic honesty. As required by these rules, to the best of my knowledge I have acknowledged ideas, thoughts, and any copyrighted material in accordance with the standard referencing rules. I certify that any part of this thesis has not been submitted for a degree or diploma in another educational institution.

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ABSTRACT

This thesis investigates how design practices and digital fabrication technologies can be systematically integrated into undergraduate gastronomy education, as well as the impact of such integration on students' creative processes, learning experiences, and professional preparedness. Moving beyond the short-term interventions that dominate the current literature, the research is grounded in a four-semester longitudinal integration implemented within a core gastronomy course. Throughout this process, students produced personalized stencil and mold prototypes for culinary preparation and presentation, and tested these prototypes across different plate configurations. Data were collected through surveys, semi-structured interviews, focus group sessions, studio observations, student artefacts, and reflective documents, and were analyzed using thematic and content analysis methods. The findings demonstrate that sustained engagement with design-oriented workflows enhances students' ideation and prototyping skills. Furthermore, students' use of prototypes across varied plate arrangements and combinations revealed the diversity in their design approaches.The study proposes a multi-semester integration model that outlines pedagogical strategies and scaffolding steps for embedding design practices and digital fabrication technologies into gastronomy education. Overall, the findings show that long-term integration supports students' creative and technical development while providing a sustainable framework that aligns gastronomy education with contemporary industry expectations and emerging digital production cultures.

Keywords: Digital tool, gastronomy class, culinary education, design with food, mold

ÖZET

Bu tez, tasarım pratikleri ile dijital üretim teknolojilerinin lisans düzeyindeki gastronomi eğitimine nasıl sistematik biçimde entegre edilebileceğini ve bu entegrasyonun öğrencilerin yaratıcı süreçleri, öğrenme deneyimleri ve mesleki hazırlıkları üzerindeki etkilerini incelemektedir. Araştırma, kısa süreli çalışmalara odaklanan mevcut literatürün ötesine geçerek dört dönem boyunca yürütülen uzunlamasına bir entegrasyon sürecine dayanmaktadır. Bu süreçte öğrenciler, özgün tabak hazırlama ile sunum süreçlerine yönelik kişiselleştirilmiş şablon ve kalıp prototipleri üretmiş; geliştirdikleri bu prototipleri farklı tabak kurgularında test etmiştir. Veriler; anketler, yarı yapılandırılmış görüşmeler, odak grup çalışmaları, stüdyo gözlemleri, öğrenci çıktıları ve yansıtıcı dokümanlar aracılığıyla toplanmış; tematik ve içerik analizleriyle bütüncül biçimde değerlendirilmiştir. Bulgular, tasarım odaklı iş akışlarıyla uzun süreli etkileşimin öğrencilerin fikir geliştirme ve prototipleme becerilerini güçlendirdiğini göstermektedir. Ayrıca, öğrencilerin prototipleri farklı tabak düzenlerinde ve kombinasyonlarda kullanma biçimleri, tasarım yaklaşımlarındaki çeşitliliği görünür kılmıştır. Çalışma, tasarım pratikleri ve dijital üretim teknolojilerinin gastronomi eğitimine bütüncül şekilde entegre edilmesine yönelik pedagojik stratejiler ile kademeli yapılandırma adımlarını içeren çok dönemli bir model önermektedir. Bulgular, uzun vadeli entegrasyonun öğrencilerin yaratıcı–teknik gelişimini desteklediğini ve gastronomi eğitimine sektörle uyumlu sürdürülebilir bir yapı kazandırdığını göstermektedir.

Anahtar Kelimeler: Dijital araç, gastronomi eğitimi, mutfak eğitimi, yemekle tasarım, kalıp

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LIST OF ACRONYMS AND ABBREVIATIONS

DBR: Design-Based Research

HCI: Human-Computer Interaction

HFI: Human-Food Interaction

FDP: First Design Presentation

SDP: Second Design Presentation

1. INTRODUCTION

Culinary education has historically been shaped by the master–apprentice model, which functions as a pedagogical framework grounded in repetition, precision, and hierarchical knowledge transfer (Murakami & Lehrer, 2022). While this model has successfully cultivated technical proficiency and discipline, it has also constrained creativity, experimentation, and reflective problem-solving within formal gastronomy training. In the contemporary landscape, however, chefs are increasingly expected to go beyond technical mastery and to combine craftsmanship with creativity, leadership, communication, and conceptual thinking (Sarıoğlan, 2013; Van Doleweerd & Bruns Alonso, 2023; Vogel et al., 2021). This shift reflects a broader transformation in the culinary profession, where the growing demand for personalized, multisensory, and experience-driven dining has redefined what it means to be a professional chef (Gayler et al., 2022; Sweetapple & Warriner, 2017).

In parallel, design thinking has emerged as a vital pedagogical and creative framework in gastronomy education. The "Design with Food" approach conceptualizes cooking as an iterative and exploratory process that involves ideation, prototyping, and reflection (Gayler et al., 2022; Kutlusoy, n.d.; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024). Within this perspective, food is not merely a consumable object but rather a medium for design inquiry that embodies sensory, cultural, and aesthetic dimensions. Design methodologies such as sketching, model-making, and iterative refinement enable culinary students to move beyond recipe replication toward creative authorship and critical engagement (Cankül, 2019; Mitchell et al., 2013). These developments mark a transition from skill-based to design-based education, aligning gastronomy with other creative disciplines in which iterative making and reflective practices are central to learning.

Technological advancements have further accelerated this pedagogical evolution. The field of Digital Gastronomy, as defined by Zoran and colleagues (Zoran & Coelho, 2011; Zoran & Cohen, 2018), explores how computational design, digital fabrication, and hybrid creative processes reshape food production, presentation, and experience. Tools such as 3D printers, laser cutters, CNC routers, and vacuum formers allow chefs and students to prototype edible structures, fabricate molds and stencils, and explore new material aesthetics (Lee et al., 2017; Lee et al., 2019; Weiler, 2020; Dolejšová et al., 2020; Mizrahi et al., 2016). Although high-end 3D food printing technologies remain limited by technical and financial barriers (Güneş et al., 2018; Kutlusoy, n.d.; Mizrahi et al., 2016), more accessible fabrication tools, such as FDM 3D printers and laser cutters, have opened new pedagogical opportunities for integrating computational design into culinary education. These tools not only foster material experimentation but also cultivate digital literacy and cross-disciplinary collaboration among students.

This technological trajectory aligns closely with the growing discourse on Human–Food Interaction (HFI), which examines how digital tools mediate human engagement with food across sensory, experiential, and cultural dimensions (Deng et al., 2021; Gayler et al., 2022; Dolejšová et al., 2020). Within this framework, food becomes a site of interaction, where materiality, technology, and human perception intersect. Digital fabrication, tangible interfaces, and multisensory design approaches expand culinary practice beyond the kitchen, enabling chefs and students to reimagine the creative process as a form of experiential, user-centered design. Consequently, gastronomy now sits at the intersection of craft, computation, and sensory experience, challenging educators to rethink how culinary knowledge is taught and embodied.

Despite these advances, research consistently highlights that gastronomy education has not yet fully integrated design methodologies or digital fabrication tools into its curricula (Antlej et al., 2017; Pengelly et al., 2012; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024). Most existing initiatives remain short-term, exploratory, or technologically isolated, limiting opportunities for students to engage in sustained, iterative learning. Studies in design-based education emphasize that creativity, technological fluency, and reflective practice develop progressively over time through cycles of making, testing, and refinement (Design-Based Research Collective, 2003; Sawyer, 2012). The absence of longitudinal, multi-semester integration models thus represents an important pedagogical gap.

Responding to this gap, the present thesis investigates the multi-semester integration of design thinking and digital fabrication tools in an undergraduate gastronomy program. Through four consecutive iterations of an applied course, it explores how students develop design literacy, creative confidence, and technical proficiency; how digital fabrication mediates their engagement with materials and aesthetics; and how these experiences contribute to professional readiness. By analyzing student artefacts, process documentation, and reflective data, this study contributes to the emerging fields of digital gastronomy, design-driven culinary education, and Human–Food Interaction. It provides one of the first longitudinal perspectives on how design-based and technological practices can be systematically embedded into gastronomy curricula to cultivate the next generation of innovative, digitally literate culinary professionals.

1.1 Background and Literature Review

1.1.1 Evolution of Culinary Education and Emerging Industry Demands

Historically, culinary education has evolved within the master–apprentice model, emphasizing strict recipe adherence, repetition, and hierarchical transmission of expertise (Murakami & Lehrer, 2022). While this traditional approach has proven effective in cultivating technical proficiency, it often constrains creativity and limits the integration of design-oriented and reflective thinking within the learning process (Mitchell et al., 2013; Cankül, 2019).

Recent educational paradigms advocate a more balanced pedagogical framework that merges theoretical foundations with practical experimentation, enabling students to develop creativity, innovation, and critical problem-solving skills (Cankül, 2019; Damsbo-Svendsen et al., 2022). Within this emerging model, culinary education is not only a vocational training system but also a platform for cultivating leadership, teamwork, and communication competencies aligned with 21st-century professional expectations (Vogel et al., 2021).

The modern culinary industry increasingly values chefs as creative leaders capable of combining artistry with management and technological adaptability (McBride & Flore, 2019). Digital transformation and the rise of *Gastronomy 4.0* have redefined professional competencies, emphasizing technological literacy, innovation management, and sustainability (Güneş et al., 2018; Seyitoğlu et al., 2025). Industry-driven examples such as the *Manufacturing 4.0 initiative at Gaya Gelato Lab* demonstrate how digital innovation reshapes both operational efficiency and creative production processes in gastronomy (Solimeno, 2017). These cases highlight that modern culinary education must integrate not only craftsmanship but also the capacity to interpret and adapt technological change.

Furthermore, the growing global demand for personalized and experiential dining underscores the need for curricula that foster interdisciplinary learning, integrating food design, sensory studies, and digital fabrication technologies (Gayler et al., 2022; Sweetapple & Warriner, 2017; Zoran, 2025). Consequently, contemporary culinary education must evolve beyond traditional craftsmanship toward a hybrid model, one that merges creative design thinking, technological fluency, and reflective practice. Such a model prepares graduates for the complexity of a digitally mediated and creatively demanding gastronomic landscape, ensuring alignment with emerging industry and academic standards.

1.1.2 Design Thinking and Creative Practices in Gastronomy

Design thinking has increasingly become a central framework within contemporary gastronomy, positioning culinary creation not merely as a technical exercise but as an iterative and exploratory design process. While design thinking frameworks (e.g., Brown, 2008; Cross, 2001; Schön, 1983) offer widely adopted models of iterative inquiry and reflective practice, their direct application to gastronomy requires greater domain-specific articulation. Addressing this need, Zampollo and Peacock (2016) introduce *Food Design Thinking* as a branch of design thinking specifically developed for food-related design processes, emphasizing eating situations and the iterative relationship between ideation, prototyping, and evaluation. Within gastronomy education, this approach provides a conceptual bridge between design thinking and culinary practice by framing food creation as a deliberate, reflective, and design-led process rather than a purely technical or intuitive activity (Zampollo & Peacock, 2016).

This perspective resonates with broader design research that conceptualizes creative practice as a cyclical process of making and reflection, and is further reflected in the "Design with Food" approach, which frames cooking as an embodied and multisensory act involving aesthetic decision-making, material exploration, sensory engagement, and cultural expression (Gayler et al., 2022; Kutlusoy, n.d.).

Within this framework, food becomes a medium for design inquiry rather than solely a product of culinary technique. Through methods such as ideation, sketching, prototyping, and iterative refinement, design-based practices enable students to investigate form, texture, and presentation in more experimental and reflective ways (Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024; Lee et al., 2017). The iterative nature of design thinking, grounded in cycles of inquiry, trial and error, and revision, supports the development of creative problem-solving skills and encourages students to move beyond conventional culinary boundaries toward innovation and self-expression.

Recent scholarship emphasizes that gastronomy education is shifting toward a multidimensional paradigm that integrates creativity, critical thinking, cultural imagination, and user-centered reasoning alongside technical skills (Cankül, 2019; Mitchell et al., 2013; Damsbo-Svendsen et al., 2022). Human-Centered Design (HCD) and Constructive Design Research (Koskinen et al., 2011) offer methodological foundations for engaging with food from the perspective of user experience and interaction. These approaches allow both students and chefs to conceptualize dishes as experiential, interactive, and contextually situated artefacts, thereby blurring the boundaries between making, performing, and sensing (Wang et al., 2024; Gayler et al., 2022).

Integrating design thinking into culinary education therefore plays a crucial pedagogical role: it cultivates creativity, enhances aesthetic sensibility, and equips learners with the cognitive and methodological tools necessary to respond to the industry's growing demand for originality, personalization, and experience-driven gastronomy (Mitchell et al., 2013; Gonera et al., 2024). As the sector increasingly values innovation, storytelling, and sensory engagement, design-based practices provide a vital pathway for developing the next generation of reflective, adaptive, and design-literate culinary professionals.

1.1.3 Digital Gastronomy and Digital Fabrication Technologies

The rapid development of digital fabrication technologies has fundamentally reshaped culinary innovation, giving rise to what is now widely recognized as Digital Gastronomy. This emerging field examines how computational design workflows, fabrication tools, and hybrid creative processes transform culinary production, presentation, and sensory experience (Zoran & Coelho, 2011; Zoran & Cohen, 2018). At its core, digital gastronomy merges craftsmanship and computation, positioning food as both a material and a medium through which technological and cultural experimentation can occur (Zoran, 2025).

Technologies such as 3D food printers, laser cutters, CNC routers, vacuum forming machines, and silicone molding systems extend the creative and technical capacities of chefs by enabling precise manipulation of form, structure, and texture (Dolejšová et al., 2020; Mizrahi et al., 2016; Lee et al., 2017; Lee et al., 2019; Weiler, 2020). By bridging design thinking with culinary practice, these technologies encourage chefs and students to reconceptualize food preparation as a process of digital craftsmanship and creative inquiry. Building on the principles of Food Design Thinking, Zampollo and Peacock (2016) conceptualize food creation as an iterative design process in which ideas are externalized, tested, and refined through material experimentation. Within this framework, digital fabrication tools extend the prototyping phase of the food design process by enabling students to translate digital concepts into tangible culinary artefacts and to engage in rapid cycles of making, evaluation, and redesign supported by sensory feedback. In gastronomy education, digital fabrication thus functions not only as a technical resource but as a pedagogical mechanism that reinforces iteration, prototyping, and experiential learning, aligning closely with broader Food Design perspectives (Zampollo & Peacock, 2016). Within the field of Food Design, digital gastronomy can be understood as a practice situated between *Design With Food* and *Design For Food*, where both edible artefacts and the tools used to produce them are subject to intentional design processes. Zampollo (2017; 2024) emphasizes that Food Design extends beyond the aesthetic treatment of food to include the design of materials, instruments, and production methods, positioning digital fabrication technologies as integral components of contemporary food design practice.

While 3D food printing has received considerable attention as the hallmark of digital gastronomy, studies emphasize ongoing technical and pedagogical challenges, such as material incompatibility, limited scalability, and the need for interdisciplinary expertise, that restrict its broader adoption in educational contexts (Güneş et al., 2018; Kutlusoy, n.d.; Mizrahi et al., 2016). Consequently, more accessible tools like FDM 3D printers, laser cutters, and vacuum formers have become increasingly relevant in culinary education. These technologies allow learners to design and fabricate molds, stencils, structural components, and plate elements that translate digital ideas into tangible food artefacts (Miyatake et al., 2022; Mayku, n.d.-a; Craft Yapı, n.d.). Their adaptability supports design-oriented pedagogies by linking conceptual ideation with hands-on fabrication.

Contemporary practice also illustrates how these tools are shaping new aesthetic and creative possibilities in the culinary field. For example, chefs such as Dinara Kasko employ parametric modeling and custom 3D-printed molds to create geometrically complex, digitally inspired pastry forms (Kasko, n.d.), demonstrating how computational fabrication is becoming an integral part of creative gastronomic expression. The integration of digital fabrication in gastronomy education aligns with maker pedagogy and learning-by-making frameworks, emphasizing creativity, experimentation, and reflective practice (Blikstein, 2013; Hsu et al., 2017), both of which highlight how making and digital fabrication support iterative, exploratory learning. Within this paradigm, food becomes a medium for computational exploration, bridging sensory experience, material interaction, and technological innovation. This aligns closely with the broader Human–Food Interaction (HFI) discourse, which investigates how digital tools mediate multisensory and interactive engagements with food (Dolejšová et al., 2020; Gayler et al., 2022).

Ultimately, digital fabrication not only enhances culinary creativity and precision but also redefines gastronomic education as a hybrid activity at the intersection of craft, computation, and experiential learning. By embedding these tools within design-based curricula, educators can cultivate a new generation of chefs who approach gastronomy as both an artistic and technological practice, capable of navigating the material and digital dimensions of culinary innovation.

1.1.4 Evolution of Culinary Tools and Material Practices

The evolution of culinary tools has continuously mirrored chefs' creative ambitions and their pursuit of greater precision, personalization, and sensory expression. Traditional implements, such as knives, molds, and stencils. Have long served as extensions of craftsmanship, mediating control, texture, and aesthetic form in food preparation. However, with the growing influence of design methodologies and digital fabrication technologies, the role of these tools has shifted from purely functional to deeply creative and expressive (Lee et al., 2017; Lee et al., 2019; Mizrahi et al., 2016; Weiler, 2020; Zoran & Cohen, 2018).

Within this emerging paradigm, digital tools such as laser cutters, 3D printers, and CNC milling systems allow chefs to reimagine the plate not merely as a surface for presentation but as a designed artefact that conveys personal style and conceptual intention. Through these technologies, culinary professionals are increasingly able to craft bespoke molds and stencils that reflect individual aesthetic identities and enhance the sensory narrative of dining (Lee et al., 2017; Mayku, n.d.-a; Miyatake et al., 2022; Dolejšová et al., 2020; Mizrahi et al., 2016). The plate becomes an interactive canvas, an intersection of design, materiality, and taste, where creative authorship extends beyond the dish itself to the tools and processes that shape it. Within the Food Design framework, culinary tools and material practices are understood not merely as neutral instruments, but as designed artefacts that actively shape creative processes and food experiences. Zampollo (2017; 2024) emphasizes that Food Design encompasses the intentional design of tools, materials, and production methods, positioning tool-making as a critical site of innovation within food-related practices. From this perspective, the evolution of culinary tools, particularly through digital fabrication, extends chefs' creative agency by enabling new forms of material exploration, customization, and experimentation that directly influence how food is conceived, produced, and experienced.

Recent industry developments further illustrate how digital fabrication reshapes tool-making practices in gastronomy. Specialized producers, such as firms developing custom, parametrically designed silicone or PLA molds through 3D modeling workflows, have emerged to support chefs seeking highly personalized geometries. Companies like MoldBrothers exemplify this shift by providing digitally fabricated, chef-specific mold systems that expand both aesthetic possibilities and material experimentation in contemporary kitchens (MoldBrothers, n.d.).

This evolution also reveals a growing educational potential: as gastronomy students engage with the design and fabrication of customized culinary tools, they not only acquire technical competencies but also develop aesthetic awareness and creative agency. The increasing accessibility of custom digital mold production, whether through in-house fabrication or collaboration with specialized producers, supports iterative cycles of making, testing, and refinement, enabling learners to experience food as a tangible design material shaped through both digital and manual processes. By iteratively designing, testing, and refining molds and stencils, learners experience food as a tangible design material that can be manipulated to evoke visual, tactile, and emotional responses (Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024; Pengelly et al., 2012). This approach bridges design-based learning with culinary craftsmanship, fostering a new generation of chefs who understand making as both a technical and reflective act, where every tool embodies an opportunity for experimentation, storytelling, and sensory innovation.

1.1.5 Human–Food Interaction (HFI) as a Theoretical Lens

Human–Food Interaction (HFI) has emerged as a rapidly developing interdisciplinary field within Human–Computer Interaction (HCI), focusing on how people engage with food through technological, sensory, and experiential dimensions (Deng et al., 2021; Gayler et al., 2022). Rather than treating food solely as a consumable product, HFI conceptualizes it as an interactive artefact, one that mediates social encounters, multisensory perception, and creative expression. This paradigm shift redefines food as a medium for design exploration, where digital tools and computational processes become integral to shaping form, material, and meaning in gastronomy.

Within this context, HFI bridges the domains of interaction design, tangible computing, and culinary creativity, providing conceptual and methodological foundations for understanding how digital technologies mediate human–food relationships (Dolejšová et al., 2020; Zoran & Coelho, 2011). Through experimental and speculative design methods, HFI researchers explore how food-related experiences can be enhanced, transformed, or reimagined through technological mediation. For example, digital gastronomy practices, such as computationally shaping edible materials, fabricating molds through digital modeling, or integrating interactive and sensory feedback in presentation, illustrate how digital fabrication becomes a mode of creative and experiential inquiry.

In gastronomy education, HFI offers a valuable theoretical lens for rethinking how chefs and students learn through hands-on, multisensory, and reflective engagement. By emphasizing experiential learning through interaction, HFI aligns with educational approaches that value creativity, iteration, and material experimentation. The inclusion of digital fabrication tools (e.g., 3D printers, laser cutters, vacuum formers) within this framework supports design-based learning practices that allow students to explore food as both a material system and an experiential interface (Deng et al., 2021; Gayler et al., 2022; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024).

Ultimately, HFI contributes to a deeper understanding of how technological mediation transforms the way food is designed, prepared, and experienced. By integrating perspectives from interaction design and digital gastronomy, HFI provides a conceptual bridge between technological innovation, creative practice, and culinary pedagogy, positioning gastronomy as a hybrid discipline grounded in sensory interaction, material thinking, and reflective experimentation.

1.1.6 Gaps and Challenges in Gastronomy Education

Existing literature identifies several persistent gaps in contemporary gastronomy education. First, digital fabrication technologies including 3D printers, laser cutters, CNC routers, and vacuum formers remain largely absent from traditional culinary curricula, leaving students with limited exposure to emerging technological and computational methods (Antlej et al., 2017; Pengelly et al., 2012). Although these tools provide new creative opportunities for shaping form, structure, and presentation in culinary design, their adoption within educational environments has not kept pace with the technological transformation occurring across the industry (Eidler, 2024; Gonera et al., 2024; Mitchell et al., 2013). This lack of integration underscores a broader gap between industry innovation and educational adaptation, suggesting that culinary education must evolve to incorporate design-oriented and technology-mediated learning experiences.

Research in maker education demonstrates similar challenges: digital fabrication and making practices often enter classrooms in fragmented, tool-centered ways that fail to support coherent learning progressions (Hsu et al., 2017). Additionally, limited access to equipment, uneven instructor expertise, and infrastructural constraints frequently result in what Blikstein (2013) terms the "FabLab divide," where only select groups gain meaningful hands-on engagement with fabrication technologies.

Second, studies indicate that many gastronomy programs still emphasize technical repetition, recipe-based instruction, and standardized practice, which constrain students' engagement with design thinking and creative problem-solving processes (Murakami & Lehrer, 2022). From a pedagogical perspective, this limitation can be interpreted through the lens of experiential learning theory (Kolb, 1984), which posits that knowledge is constructed through cycles of experience, reflection, conceptualization, and experimentation. When culinary education neglects iterative, hands-on, and reflective modes of learning, it inhibits students' ability to internalize complex creative processes and develop adaptive expertise, skills increasingly required in contemporary gastronomy. Furthermore, maker-oriented research shows that overly structured learning environments restrict opportunities for playful exploration and iterative tinkering, which are essential for developing creative confidence (Resnick & Rosenbaum, 2013). While design thinking is increasingly referenced within gastronomy education, it is often adopted in a generalized or tool-oriented manner that does not sufficiently account for the material, sensory, and experiential specificities of food-related design processes. Zampollo and Peacock (2016) argue that such generic applications overlook the complexity of culinary creation, where ideation, prototyping, sensory evaluation, and contextual interpretation occur simultaneously rather than as discrete stages. As a result, students are frequently exposed to isolated design exercises or short-term interventions that fail to support the development of sustained design literacy and reflective practice. The absence of a food-specific design framework, such as Food Design Thinking, contributes to fragmented learning experiences and limits students' ability to internalize iterative and design-led approaches within gastronomy education (Zampollo & Peacock, 2016).

Third, the literature reveals a lack of systematic pedagogical research examining the long-term integration of design-based and digital fabrication approaches in culinary education. Most existing studies are short-term, exploratory, or technology-specific, offering limited insight into how students develop sustained creative capacities and technological literacy through extended exposure (Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024). This absence highlights a need for design-based research methodologies, which emphasize iterative experimentation, contextual adaptation, and the longitudinal refinement of educational interventions (Design-Based Research Collective, 2003). Such approaches could enable researchers and educators to trace how digital fabrication practices evolve over multiple semesters and how they contribute to the formation of creative and reflective culinary professionals.

Finally, while gastronomy education increasingly recognizes the role of creativity and innovation, there remains limited exploration of how maker-oriented pedagogies, which prioritize tinkering, material exploration, and iterative learning, can be systematically integrated into curricula. Within this context, Resnick and Rosenbaum (2013) argue that "designing for tinkerability" allows learners to build creative confidence by exploring, failing, and iterating through open-ended making processes. This perspective aligns strongly with the goals of digital gastronomy education, where students engage with technologies not merely as tools of production but as catalysts for conceptual thinking, sensory experimentation, and interdisciplinary collaboration.

In summary, current gastronomy education continues to lag behind both industry and technological advancements, particularly in integrating digital tools, experiential learning, and design-based pedagogy. Addressing these gaps requires structured, multi-semester learning environments that provide consistent opportunities for making, iteration, and reflective technological engagement (Blikstein, 2013; Hsu et al., 2017). Such an approach would support the cultivation of a new generation of chefs who are not only technically proficient but also design-literate, reflective, and capable of navigating the evolving intersections of craft, technology, and creativity.

1.1.7 Toward Longitudinal and Design-Based Integration Models

Existing studies indicate that the integration of design practices and digital fabrication technologies into gastronomy education is predominantly confined to short-term workshops, isolated courses, or exploratory interventions (Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024). While these initiatives demonstrate the potential of design-based and technology-mediated approaches to foster creativity and sensory awareness, they provide limited insight into how such competencies develop through sustained engagement over time. From an experiential learning perspective, Kolb (1984) emphasizes that deep learning emerges through repeated cycles of experience, reflection, conceptualization, and experimentation, suggesting that short-term instructional formats are insufficient for internalizing complex creative processes.

Design-based research further reinforces the need for longitudinal integration by conceptualizing learning environments as iterative systems that evolve through cycles of design, enactment, analysis, and refinement within authentic educational contexts (Brown, 1992; Design-Based Research Collective, 2003; Cobb et al., 2003). Within this framework, Food Design Thinking offers a domain-specific rationale for extended and iterative curricular structures in gastronomy education. Zampollo and Peacock (2016) conceptualize food design as a cyclical and reflective process in which ideation, prototyping, sensory evaluation, and contextual interpretation unfold through repeated iterations rather than isolated stages. When embedded across multiple semesters, such an approach enables students to progressively develop design literacy, creative confidence, and technological fluency, while allowing educators to iteratively refine course content and instructional strategies.

Consequently, longitudinal and design-based integration models are essential for establishing sustainable and transferable approaches to digital gastronomy education, ensuring that iterative improvements contribute not only to immediate learning outcomes but also to long-term pedagogical insight and professional preparedness.

1.2 Aims and Objectives

The primary aim of this research is to examine how design-based learning approaches and digital fabrication technologies can be integrated into gastronomy education through a multi-layered, long-term, and systematic model. Contemporary discussions in digital gastronomy, design-oriented practice, and Human–Food Interaction (HFI) highlight that modern culinary professionals must not only demonstrate technical proficiency but also cultivate competencies in creative problem-solving, material-driven thinking, technological literacy, and experiential design. In alignment with these developments, this thesis investigates the evolution of an undergraduate gastronomy course; iteratively developed across four semesters and implemented in its final form during the study period to understand how students' creative processes, design literacy, digital fabrication competencies, and professional readiness transform through sustained engagement.

The motivation of this research arises from the observation that current literature on the integration of digital fabrication tools (e.g., 3D printing, laser cutting, vacuum forming, silicone mold production) and design practices into gastronomy education remains predominantly limited to short-term workshops, fragmented demonstrations, or technology-centered interventions. While such studies contribute to raising awareness of creativity and technology in culinary contexts, they provide limited insight into the long-term development of learning outcomes, iterative design processes, or multi-stage prototyping cycles (Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024; Antlej et al., 2017; Pengelly et al., 2012). Addressing this gap, the present study aims to propose a comprehensive model that accounts for the multi-semester evolution of course content and iterative refinements, thereby expanding current understandings of how digital fabrication can meaningfully support learning in gastronomy.

In line with this aim, the specific objectives of the research are as follows:

- To examine students' engagement with design-based processes, including ideation, sketching, prototyping, iteration, and refinement within a gastronomy context.
- To evaluate the integration of digital fabrication technologies into culinary applications, and to analyze how tools such as Fusion 360, laser cutters, 3D printers, 3D scanners, vacuum forming, and silicone mold making contribute to students' technical proficiency and material understanding.
- To systematically analyze the four-semester evolution of the course, documenting instructional methods, tools, and content transformations, and assessing how iterative improvements influence student outcomes and creative production processes.

- To explore students' perceptions of personal and professional development, including self-confidence, creative competence, collaborative practices, and readiness to adopt digital fabrication technologies in their future careers.
- To propose a sustainable and applicable design-oriented integration model for gastronomy education, outlining long-term strategies for incorporating digital fabrication and design thinking into culinary curricula.

Research Questions (RQs):

RQ1. *How can design practices and digital fabrication technologies be effectively integrated into undergraduate gastronomy education?*

RQ2. *What are the potential impacts of this integration on students' learning processes, creative abilities, technical competencies, and perceptions of professional preparedness?*

RQ3. *How do the iterative improvements implemented across four semesters contribute to the development of a sustainable and transferable integration model for digital gastronomy and design-based learning?*

2. OVERVIEW OF THE COURSE PLAN

2.1 General Structure of the GARM 423 Courses

2.1.1 Course Context and Objectives

GARM423 – *Culinary Exhibitions and Seminars* is a compulsory senior-year course offered by the Department of Gastronomy and Culinary Arts in the Faculty of Applied Sciences at Özyeğin University. The course is conducted by professional chefs from *Le Cordon Bleu İstanbul* and aims to extend the boundaries of traditional gastronomy education. It seeks to cultivate chefs and entrepreneurs who are internationally recognized and capable of generating creative and economic value within the global gastronomy sector. Throughout the 14-week semester, students are expected to engage in both individual and group-based activities that culminate in the development and presentation of original menus during jury evaluations.

The course plan is organized into two main phases. The first phase focuses on preparation, conceptual development, and design-based applications leading to the jury presentation of the students' first original menu. The second phase involves students who have gained experience from the initial process, now preparing a second, final menu composed of original dishes and presenting it at the concluding jury session. During the semester, students are provided with two different ingredient lists at separate intervals. Using these lists, they are required to design and produce complete menus consisting of an amuse-bouche, a starter, a main course, and a dessert. While each student individually develops and prepares dishes on a weekly basis, they collaborate as a group when deciding on the final menu to be presented to the jury. This decision-making and refinement process occurs iteratively for each dish every week and continues until the end of the semester. Ultimately, each student participates in two separate teams and contributes to the creation of two distinct menus. Students are thus expected not only to develop advanced technical cooking abilities but also to enhance managerial, creative, and innovative thinking competencies through this process.

The overall aim of the course is to train students as multifaceted gastronomy professionals who can operate effectively in both professional kitchen environments and food and beverage management contexts. Within this framework, students are encouraged to integrate the foundational knowledge they have acquired in previous semesters, such as food science, hygiene, nutrition, and sustainability, into applied culinary processes. At the same time, they learn to critically analyze the role of culture, art, and creativity in gastronomy. By the end of the semester, students are expected to become individuals who can think through design-based approaches, synthesize digital production technologies with contemporary cooking techniques, and generate innovative culinary solutions while exhibiting advanced communication and leadership skills. In this way, the course contributes to the development of entrepreneurial, decision-making, and collaborative chefs capable of competing in the global gastronomy landscape.

Beginning with the Fall semester of the 2023–2024 academic year, the course has been enriched with sessions held in the university's digital fabrication laboratory, *Openfab (FabLab)*, alongside conventional kitchen-based practices. This dual structure offers students the opportunity to build a bridge between traditional culinary craftsmanship and technological innovation. Through this integration, students have been introduced to design practices and digital fabrication tools, gaining first-hand experience in merging these approaches with culinary creation processes. Consequently, they are able to combine traditional and modern cooking knowledge with contemporary design and digital production technologies. By redefining the kitchen studio as an experiential and reflective learning environment, the course aims to foster unique gastronomic experiences that emerge from the convergence of design, craftsmanship, and technology.

2.1.2 Learning Environment and Student Profile

As of the Fall semester of the 2023–2024 academic year, the GARM423 – *Culinary Exhibitions and Seminars* course has been conducted within a hybrid learning environment that combines professional kitchen practices with design-oriented laboratory work. This dual structure divided between *Le Cordon Bleu*, a fully equipped culinary training space, and *Openfab (FabLab)*, the university's digital fabrication laboratory, enables students to work simultaneously with both traditional and modern gastronomic techniques as well as with digital design and production processes. In doing so, the course provides an experiential learning platform in which creativity, material experimentation, and technological literacy are integrated into gastronomy education.

All course activities are carried out in person, with hands-on learning and immediate feedback forming the basis of the pedagogical approach. Within the weekly schedule, students engage concurrently in culinary practices and digital fabrication tasks, often alternating between the two environments within the same week. Reflecting a design studio model, this structure encourages reflective thinking, iteration, and peer learning among students. Each week, students are introduced to new technological tools such as Fusion 360, 3D printers, laser cutters, vacuum-forming devices, and silicone molding equipment. They employ design practices and digital tools to create prototypes of the elements they develop for individual and group menu projects.

The course participants are typically senior undergraduate students in the Gastronomy and Culinary Arts program. By the time they take this course, most have already gained professional experience through internships or employment in national or international restaurants. In the Spring 2023 semester, 12 students were enrolled in the course; in the Fall 2023 semester, 23 students; in the Spring 2024 semester, 22 students; and in the Fall 2024 semester, during which this research and data collection were conducted, a total of 29 students participated. Except for the Spring 2023 semester, students in all other terms were divided into two groups to ensure the effective use of kitchen and laboratory facilities.

The learning environment of GARM423 establishes a balance between discipline and exploration by combining the rigor of professional kitchen training with the exploratory approach of a design studio. Throughout their projects, students use the kitchen space for food preparation, cooking, and presentation, while employing the Openfab laboratory to prototype molds and templates to be used during the cooking process (Figure 2.1). The coordination and management of workflow between these two spaces, both located within the same campus, are the responsibility of the students. The outcomes of this integration were reflected in the final jury evaluations, particularly in the presentation and plating of the dishes.

Figure 2.1 *Learning Environments Used Throughout the GARM423 Course*

Note. Including the Le Cordon Bleu kitchen, Openfab (FabLab) and the jury presentation space.

2.2 Evolution of the Syllabus Across Four Semesters

Between 2023 and 2025, the GARM423 – *Culinary Exhibitions and Seminars* course evolved over four consecutive semesters, during which the integration of design-based approaches and digital fabrication tools were iteratively developed. Each iteration of the course was restructured based on the insights and findings obtained from the previous implementation, progressively establishing a stronger balance between its technical and creative dimensions. The integration process was developed in alignment with the overall objectives of the course, while also considering the facilities available in both the professional kitchens and the Openfab digital fabrication laboratory. Without altering the original four-hour class duration, this integration was evaluated and refined throughout a consistent 14-week semester format.

Within the Openfab environment, the digital tools, design practices, and prototyping materials that could be incorporated into the course were identified as a preliminary step. Before these components were formally embedded into the syllabus, consultations with the professional chefs leading the course ensured coherence between the culinary and digital production elements. Throughout this period, students followed a sequential learning trajectory encompassing computer-aided design, laser cutting, 3D printing, and subsequently, vacuum forming and silicone molding techniques. This staged structure supported students' transition from two-dimensional surface design to three-dimensional form generation, enabling the concurrent development of conceptual understanding and hands-on technical skills within the context of culinary education.

It was determined that the design files required for digital fabrication would be produced using Fusion 360 software. The process began with two-dimensional digital drawing, followed by the fabrication of templates through laser cutting. Laser cutting was selected as an accessible entry point into digital production, as it enables the rapid generation of tangible outputs and allows students to directly observe material behavior. Following this introductory phase, students advanced to three-dimensional modeling on the computer and produced their digital forms using 3D printers. These printed objects were subsequently employed both in plating presentations and in vacuum-forming and silicone-molding processes. Through this progression, students were able to directly observe the physical and gastronomic implications of their digital design decisions.

2.2.1 First Application: First Integration of the Design-Based Approach

The integration of design-based practices into the GARM423 course was first implemented in the Spring semester of the 2023–2024 academic year. This period represented an experiential and formative starting point for incorporating design-oriented thinking into the structure of gastronomy education. The first implementation introduced the university's FabLab facilities and accessible digital fabrication materials into the existing course framework, thereby adding a new dimension to traditional culinary training. This initial semester established the foundational principles that would shape the model developed in the following three iterations. Application durations, the role of digital tools within the course, and evaluation methods were restructured based on the outcomes of this first experiment. Observations regarding students' learning pace and technical proficiency also served as important references for subsequent program revisions.

A total of seven out of the fourteen weeks of the course were dedicated to Openfab activities, conducted consecutively from the second to the eighth week. Each class session ran from 08:40 to 12:30, with the first three hours taking place in the kitchen and the final hour in the Openfab laboratory. During this initial phase, students were introduced in sequence to Fusion 360, laser cutting, 3D printing, vacuum forming, and silicone molding techniques. The course adopted a hybrid structure that allowed students to simultaneously experience both kitchen-based production and digital design processes. An overview of the course structure, digital tools, materials, and instructional insights from the first iteration is presented in Table 2.1.

Table 2.1 *An Overview of the Four-Iterations of the GARM423 Course*

	First Iteration	**Second Iteration**	**Third Iteration**	**Fourth Iteration**
Semester	2023-2024 Spring	2023-2024 Fall	2024-2025 Spring	2024-2025 Fall
Number of Students / Groups	12 Students 4 Groups	23 Students 6 Groups	22 Students 6 Groups	29 Students 8 Groups
Weekly and Hourly	7 Weeks 7 Hours	6 Weeks 6 Hours	6 Weeks 9 Hours	7 Weeks 13 Hours
Digital Tools and Prototyping	Fusion360, laser cutter, 3D printer, vacuum and silicone molding	Fusion360, laser cutter, 3D printer, vacuum and silicone molding	Fusion360, laser cutter, 3D printer, 3D scanner, vacuum and silicone molding	Fusion360, laser cutter, 3D printer, 3D scanner, vacuum and silicone molding
Materials	PetG (0.5 mm), PLA, oven-safe silicone, non oven-safe silicone, paper, cardboard	PetG (0.5 mm), silicone sheet, PLA, oven-safe silicone, non oven-safe silicone, paper	PetG (0.5 mm), PetG (0.8 mm), silicone sheet, PLA, only oven-safe silicone (10 and 15 shore), paper, cardboard, play dough	PetG (0.5 mm), PetG (0.8 mm), silicone sheet, PLA, TPU, only oven-safe silicone (5, 10 and 15 shore), paper, cardboard
Presentations	Final Design Presentation	Final Design Presentation (expanded)	First and Final Design Presentation	First and Second Design Presentation
Foundational Insight Stage	Foundational insight stage	Standardization and error identification	Technical deepening and material expansion	Stabilization and maturity of the final model

	First Iteration	Second Iteration	Third Iteration	Fourth Iteration
Key Insights	Students struggled with measurement precision and scaling.	Confusion caused by the coexistence of oven-safe and non-oven-safe silicone.	Fusion 360 issues continued but improved gradually.	Strong alignment emerged between concept and execution.
	Fusion 360's modeling logic was difficult to grasp.	Strong dependency on stencils limited 3D exploration.	3D scanning expanded access to digital modeling and creativity.	Face-to-face Fusion 360 training reduced persistent modeling issues.
	Digital tools were used sequentially rather than conceptually integrated.	Mold thickness and draft-angle errors persisted.	Increased material diversity deepened material awareness.	Iteration cycles became self-directed and stable.
	Limited time for iteration due to late Openfab scheduling.	Material misuse (mixing silicone types) produced inconsistent outcomes.	Hybrid outputs (laser + 3D print + silicone) increased significantly.	Students demonstrated high material literacy and informed selection.
	Low originality: designs closely mimicked existing chef plates or industrial molds.	Early Openfab improved flow, but iterative development still needed support.	Modeling clay enhanced understanding of angles, slopes, and mold geometry.	The use of 3D scanners is still less common compared to other technological tools

Note. Including its structure, tools, materials, and instructional insights.

Following each digital fabrication lesson, students were given one week to work independently on their designs in digital format. To support this, instructors organized 'Create Your Own Design' sessions, where students discussed their digital models and prototypes. Due to limited class time, synchronous instruction for the Fusion 360 software could not be conducted; instead, instructors prepared and shared asynchronous tutorial videos via Google Drive. This hybrid teaching model enabled students to develop time management skills and experience both culinary discipline and digital creativity concurrently.

A total of 12 students (6 female and 6 male), including two international participants, took part in this first iteration of the design integration. For kitchen work, students were divided into four groups of four. Each student was responsible for both individual and group tasks, allowing the course to maintain a balance between team-based production in the kitchen and individual creative exploration in the laboratory. As students became familiar with digital fabrication tools, they continued developing their designs in Openfab during 'Create Your Own Design' sessions. For instance, after preparing amuse-bouche dishes in Week 2, they participated in a short laser cutting and material usage workshop on the same day. In the following weeks, students applied the knowledge acquired from asynchronous videos to develop and test their stencil designs in the lab, receiving one-on-one feedback from instructors. The same iterative learning process continued for 3D printing and vacuum forming practices.

The silicone molding process was introduced but not mandatory; students were encouraged to explore its integration into their food presentations voluntarily. This flexible approach supported individual learning paces and fostered creative control throughout the process.

Student assessments were conducted collectively during the final jury. Each group was expected to present the prototypes they had developed and use them in their final dish presentations. In addition, to monitor students' individual work beyond the jury presentation, an assignment titled Final Design Presentation was created and shared with them through the LMS system. Students were required to upload their presentation one week before the final jury. The file included photos of laser-cut, 3D-printed, and molded prototypes, as well as sketch studies, dessert recipes, and detailed explanations of the stencils or molds to be used in plating.

2.2.1.1 Preliminary Insights Gained in the First Iteration

According to instructor observations, students particularly struggled with understanding measurement precision and the conceptual logic of digital modeling in Fusion 360. These challenges indicated the need to allocate more instructional time to software training in subsequent semesters, to clarify foundational modeling principles, and to provide additional applied examples. End-of-semester evaluations further revealed that students would benefit notably from being introduced to the majority of digital fabrication methods before the first jury session. This finding formed the basis for structural changes such as shifting Openfab sessions to earlier weeks of the semester and introducing an introductory presentation on digital fabrication technologies at the beginning of the course.

The evaluations also showed that conducting vacuum-forming sessions after the first jury created conceptual difficulties for students. Because they could not apply this technique during their preparation for the first jury, they struggled to establish meaningful connections between vacuum-forming and its gastronomic applications. Consequently, it was decided that Openfab sessions would no longer be scheduled on jury days in the following iterations. This adjustment aimed to ensure that students' design and prototyping processes, along with their iterative development and experiential learning outcomes, would be reflected more comprehensively and coherently in their presentations.

During the first iteration, students were required to submit only the *Final Design Presentation* prior to the final jury. In this presentation, they showcased their final designs, prototypes, and their application within the dessert plate composition. In subsequent iterations, however, the scope of this assignment was expanded: students were expected to submit sketches and design prototypes not only for the dessert course but for all four dish categories: amuse-bouche, starter, main course, and dessert. This expansion encouraged students to integrate digital fabrication processes across the full culinary workflow.

In conclusion, the first iteration represented a critical exploratory phase during which students were introduced to digital fabrication technologies, began to relate design-oriented thinking to gastronomy, and developed an initial awareness of interdisciplinary production. The insights and observations gathered during this process directly informed the structural advancements implemented in later semesters and served as a foundational reference for the current integrated structure of the GARM423 course.

2.2.2 Second Application: Structured Integration of Digital Production Processes

In the Fall semester of the 2023–2024 academic year, several structural improvements and content expansions were implemented in the GARM423 course based on the outcomes and instructor observations from the initial semester. The primary objective of this second iteration was to integrate digital production processes into the course flow in a more systematic way, ensuring that all students could experience the full range of digital tools before the first jury session.

The course maintained its fourteen-week structure, with a total of six Openfab sessions incorporated between Weeks 1 and 6. Each class took place from 08:40 to 12:30, with the first three hours conducted in the kitchen and the final hour in the Openfab laboratory. A total of 23 students (11 female and 12 male) participated in the course, including six international students. The class was divided into two main sections for instructional purposes. Within the kitchen component, students were further organized into groups of four to five, resulting in a total of five teams that presented their menus during the jury evaluations. This dual-section format aimed to ensure a balanced workload and efficient use of facilities.

Building upon the hybrid model developed in the first iteration semester, Openfab sessions were now introduced from the very first week and completed by the time of the first jury in Week 6. This adjustment allowed students to learn all digital fabrication tools early in the term and provided them with sufficient time for iteration, experimentation, and prototype refinement before the final jury.

The digital production process began with laser cutting and concluded with silicone molding, following the same sequence of tools introduced in the previous semester. However, several refinements were made. During the laser cutting sessions, students were introduced to silicone sheets as an alternative material, offering greater flexibility, thickness, and heat resistance suitable for oven processes. This enhancement allowed students to make more informed material decisions by comparing physical properties and performance.

To promote accuracy and precision in the design process, the use of rulers and measurement checks was made mandatory during this semester. Students were also instructed to perform initial laser cutting trials on white paper before switching to final materials. This systematic approach helped reduce the technical challenges encountered in Fusion 360 and encouraged a more measured, data-informed workflow. An overview of the course structure, digital tools, materials, and instructional insights from the second iteration is presented in Table 2.1.

2.2.2.1 Preliminary Insights Gained in the Second Iteration

By the end to of the semester, several major insights emerged regarding students' engagement with digital fabrication processes. First, the simultaneous use of oven-safe and non-oven-safe silicone materials introduced various practical limitations. As the functional requirements of molds shifted throughout the design and cooking stages, non-oven-safe silicone proved inadequate for heat-based applications, while the coexistence of multiple silicone types restricted students' choices during the preparation and plating processes. Additionally, some students unintentionally mixed different silicone types during casting, resulting in inconsistencies in mold quality.

It was also observed that students demonstrated a strong tendency toward producing stencils as their primary digital outputs. Although stencil fabrication supported accuracy and reproducibility, this preference led to limited exploration of 3D printing and molding techniques. To address this imbalance and encourage greater diversity in digital production, it was determined that in subsequent semesters only dishes incorporating 3D printing and/or molding techniques would be eligible for jury evaluation.

Several technical challenges were identified during the silicone molding process. Excessively thick molds created difficulties during baking or freezing, and some vacuum-formed models exhibited deformation due to insufficient draft angles or overly detailed 3D prints. In response, the instructional plan for the following semester was revised to include practical demonstrations with reference models and optimized guidelines for ideal angles, wall thickness, and surface detailing.

Another notable observation concerned students' design approaches. Throughout the semester and during jury presentations, the majority of prototype designs were found to be inspired by well-known chef plates or commercially available industrial molds. This tendency indicated limited depth in students' original form development and constrained their creative experimentation. Accordingly, a dedicated design workshop was planned for the subsequent semester to support students in reflecting on, refining, and personalizing their own design ideas.

Based on these insights, several structural adjustments were incorporated into the course for the following iteration. The dual-silicone approach was discontinued to eliminate material-related inconsistencies. Jury evaluations were restructured to require the integration of 3D printing and/or molding techniques in at least one dish. Hands-on demonstrations with reference models were introduced to address recurring technical issues, and a specialized design workshop was incorporated to strengthen form development and foster originality in students' creative processes.

Overall, these insights laid the foundation for a series of refinements that strengthened the educational model of GARM423. By the end of the second iteration, students were engaging with digital fabrication tools in a more systematic and comprehensive manner, showing notable improvements in dimensional accuracy, material awareness, and technical decision-making. This iteration marked a critical stage in clarifying the course's integrated educational framework and establishing the basis for the advanced model implemented in subsequent years.

2.2.3 Third Application: Period of Technical Deepening and Material Diversity

In the Spring semester of the 2024–2025 academic year, the GARM423 course was conducted for the third time, marking a phase of pedagogical and technical maturity.

Building upon the findings and experiences of the previous two iterations, this semester introduced a more comprehensive framework that emphasized material diversity, deeper technical engagement, and informed use of digital fabrication tools. The overarching goal was to enable students to apply digital technologies more consciously, explore a broader range of materials, and advance their design thinking through technical experimentation.

The course maintained its fourteen-week structure, with Openfab sessions running from Week 1 through Week 8. Two of these weeks did not include Openfab work due to scheduling and institutional events. In total, students participated in six active Openfab weeks, accounting for approximately nine hours of applied digital production. Five of these sessions lasted one hour each, while Week 8 featured a four-hour extended session dedicated entirely to design development in the Openfab environment. A total of 22 students (13 female and 9 male) were enrolled in the course, including two international students. Students worked in four kitchen groups, two composed of five members and two of six, balancing teamwork in the kitchen with individual creativity in the fabrication lab. An overview of the course structure, digital tools, materials, and instructional insights from the third iteration is presented in Table 2.1.

The course structure was designed to first familiarize students with the available technologies while simultaneously improving their digital drawing skills. After mastering these tools, students proceeded to develop individual design ideas for their final jury presentations. Several structural revisions were made compared to the previous semester. An *Introduction Session* was added in the first week, outlining the course objectives, technologies, and materials, alongside selected examples from previous semesters. This orientation helped students develop a holistic understanding of the digital fabrication process before entering the production phase. Fusion 360 training continued asynchronously through instructor-prepared video tutorials.

A new session titled *Create Idea Lesson* replaced the previous *Create Your Own Model* class. This change was implemented in response to observations from earlier iterations showing that many students struggled to generate original forms and frequently produced prototypes inspired by well-known chef plates or commercially manufactured molds. The revised structure shifted the emphasis from technical modeling to conceptual development, encouraging students to formulate, refine, and personalize their own design ideas before transitioning into digital production. To further support this approach, and to assist students who found computer-based modeling challenging, a 3D scanner commonly used in reverse engineering was integrated into the course for the first time. This tool enabled students to digitize physical objects such as fruits and vegetables, edit the resulting geometries in Fusion 360, and subsequently fabricate them through 3D printing. In this way, a bridging workflow was established between tangible materials and parametric digital modeling, expanding students' creative entry points into the design process.

While the primary set of digital fabrication tools remained consistent with prior semesters, notable innovations were made in both material use and production methodology. In the laser-cutting applications, the flexible 0.5 mm PETG sheet originally designed for use with the vacuum-forming machine (Mayku, n.d.) was replaced with a thicker and more rigid 0.8 mm PETG sheet, which provided enhanced structural stability and improved surface quality. This transition encouraged students to compare the behavioral differences between materials and refine their design decisions accordingly. During silicone sheet production, students experimented with varying thicknesses and learned to control fabrication parameters. For the silicone molding process, only oven-safe silicones were used, available in two hardness levels (10 Shore and 15 Shore) . The differences between these materials were discussed in class, promoting an informed understanding of elasticity, thermal performance, and mold precision. Additionally, a 3D modeling component was incorporated into mold-making, allowing students to model their own molds, regulate wall thickness, and manage geometric angles more precisely.

Two evaluations were conducted during the semester: the First Design Presentation in Week 6 and the Final Design Presentation in Week 13, held alongside the final jury. Students were required to document their fabrication processes photographically, describe their use of digital tools, and reflect on technical challenges and solutions.

2.2.3.1 Preliminary Insights Gained in the Third Iteration

Instructor observations revealed distinctive progress in students' technical accuracy, material sensitivity, and the integration of digital methods into culinary design. However, several instructional challenges persisted. Difficulties with Fusion 360, particularly regarding basic commands, scaling, and workflow organization, continued to affect students' modeling proficiency, reinforcing the need for face-to-face software training in future semesters.

Restrictions on stencil use successfully encouraged students to explore alternative digital fabrication pathways. As a result, many students produced hybrid prototypes that combined laser cutting, 3D printing, and silicone molding. The vacuum-forming process, now positioned before the jury week, was more effectively understood and executed. The introduction of modeling clay as an exploratory exercise allowed students to better visualize angles and slopes when planning mold geometry, contributing to thinner and more controlled silicone mold walls that performed more successfully in kitchen applications.

Limiting production to oven-safe silicones reduced error rates and simplified material decision-making. Additionally, repositioning the 3D scanning workflow before the molding phase allowed students to integrate scanned geometries directly into their digital models, enriching the design process. By the end of the semester, several curriculum-level adjustments were proposed based on these insights. These included the full removal of non-oven-safe silicones, the encouragement of multi-material laser cutting using PETG, silicone sheets, and paper, and the introduction of group-based ideation sessions to expand collaborative creative thinking.

Overall, the Spring 2024–2025 semester represented a pivotal phase in the evolution of the GARM423 course, marked by technical deepening, expanded material exploration, and heightened creative experimentation. Students engaged with digital fabrication tools in a more systematic and reflective manner, strengthening their understanding of the relationship between digital design and culinary craftsmanship. Increased iteration frequency, broader material trials, and multi-modal fabrication practices enhanced the creative capacity of the course, marking the transition of GARM423 into its fully developed educational model.

2.2.4 Fourth Application: Stabilization of the Final Course Model

The fourth implementation of the GARM423 course, conducted in the Fall semester of the 2024–2025 academic year, represented the culmination of insights and experiences accumulated over the previous three iterations. This phase marked the point at which the course reached its permanent and stable structure. The primary objective of this iteration was to standardize the refined methods of digital production, material use, and assessment developed in earlier semesters, thereby establishing a sustainable and replicable educational model.

The course maintained its fourteen-week structure, incorporating seven Openfab sessions that collectively totaled twelve hours of hands-on practice. These sessions began in Week 1 and continued until Week 13. The first session lasted two hours, while extended three-hour sessions were scheduled in Weeks 6 and 13, during which kitchen classes were suspended. Between these sessions, students participated in one-hour Openfab workshops following their kitchen courses. A total of twenty-nine students (23 female and 6 male), including two international students, were enrolled. Students engaged simultaneously in kitchen-based culinary applications and digital fabrication activities, achieving the fully balanced kitchen–laboratory integration envisioned in earlier iterations. The weekly structure of the fourth iteration is summarized in Table 2.1.

During this semester, Fusion 360 training was redesigned to address the modeling difficulties observed in prior iterations. A face-to-face *Fusion 360 Introduction Lesson* was incorporated to supplement the existing asynchronous video tutorials, enabling students to grasp fundamental modeling principles through direct instruction. The set of digital production tools (i.e., laser cutting, 3D printing, vacuum forming, silicone molding, and 3D scanning) was preserved, while new sessions were introduced under the titles *Generative Idea, Create Final Design*, and *Creating and Prototyping*. These additions encouraged iterative creativity, supporting both individual and group-based production throughout different stages of the design process.

As in previous semesters, the course aimed to complete all digital production processes before the first jury, complemented by additional workshop sessions and final prototyping exercises. This structure enabled students to use their self-designed stencils and molds directly during the first jury presentations. On the day of the Week 7 jury, students submitted their updated *First Design Presentation* files, while the *Second Design Presentation*, completed during the same week as the final jury, documented their individual design journeys, experiential learning processes, and iterative developments. Templates used to track students' individual progress will be detailed further in Section 3.1 (Data Collection).

A new material, modeling clay, was added to the course's material set during this semester. It was used to test students' 3D-printed cutters and facilitate in-class discussions of design outcomes. In vacuum forming sessions, the clay was also used by students who lacked pre-existing models or who needed to modify the angles of their existing geometries. For silicone mold production, manufacturer-provided materials were available in 5, 10, and 20 Shore hardness levels, letting students compare flexibility, structural integrity, and surface quality in their prototypes.

According to instructor observations, students in this semester demonstrated a remarkable increase in both technical competence and creative capacity compared to earlier cohorts. A strong alignment was observed between the course learning outcomes and students' applied processes, indicating that they were able to establish a balanced relationship among technical knowledge, material awareness, and aesthetic expression. Although some minor challenges in modeling and prototyping persisted, the overall structure achieved a sustainable, measurable, and repeatable form.

2.2.4.1 Preliminary Insights Gained in the Fourth Iteration

Instructor observations during the fourth iteration indicated a marked increase in students' technical competence, material literacy, and creative capacity. Compared to prior cohorts, students demonstrated stronger alignment between conceptual intentions and technical execution, suggesting that the finalized instructional structure enabled them to balance technical knowledge, material awareness, and aesthetic decision-making more effectively. Although minor challenges in Fusion 360 modeling and prototyping persisted, these issues were limited in scope and did not disrupt the overall workflow.

The redesign of Fusion 360 training and the addition of new ideation-focused sessions notably improved students' engagement with the digital design process. The integration of modeling clay contributed to more accurate visualization of angles, slopes, and form transitions, resulting in more successful 3D-printed components and thinner, better-controlled silicone molds. Similarly, conducting vacuum forming before the jury continued to support students' comprehension and execution of the technique.

Collectively, these insights confirmed that the instructional and material adjustments implemented throughout earlier iterations had reached a stable and reproducible form. No further major structural changes were deemed necessary, indicating that the course model had matured into a fully developed and institutionally sustainable educational framework.

With this semester, the developmental process of the GARM423 course reached completion, and the application model stabilized into its final form. Section 2.3 (*Final Course Design*) presents a detailed overview of this finalized model, including the weekly plan, materials and tools, digital fabrication workflow, and assessment methods that collectively define the mature educational structure of the course.

2.2.5 Double Diamond Model as an Analytical Framework

The four-semester development of the GARM423 course demonstrates a multi-phased, iterative, and feedback-driven learning structure. In order to analyze this process in a coherent and systematic manner, the Double Diamond model is adopted in this study as an analytical framework. Originally developed by the Design Council, the Double Diamond conceptualizes the design process through four interconnected stages (*Discover, Define, Develop,* and *Deliver*) emphasizing cycles of divergence and convergence rather than linear progression (Design Council, 2005).

The Double Diamond model is widely used to interpret non-linear, experience-based, and iterative design processes. As such, it aligns closely with studio-based design pedagogy and prototyping-centered learning approaches (Lawson, 2005; Schön, 1983). The pedagogical structure of GARM423, characterized by the integration of professional kitchen practice and digital fabrication, jury-based feedback mechanisms, and iterative prototyping, corresponds strongly with the exploratory and reflective nature proposed by the model.

The first iteration of the course can be interpreted as a *Discover* phase, during which students encountered digital fabrication tools, materials, and design concepts for the first time. The technical challenges and uncertainties observed during this period contributed to the expansion of the problem space. In the second iteration**,** the restructuring of the course schedule and the relocation of digital fabrication sessions prior to the first jury enabled a clearer articulation of learning objectives, marking a transition toward the *Define* phase of the model.

The third iteration reflects the *Develop* phase, characterized by intensive prototyping, material experimentation, and increased iteration cycles. During this stage, students actively explored alternative solutions by combining multiple fabrication techniques, allowing design decisions to emerge through hands-on experimentation. The fourth and final iteration corresponds to the *Deliver* phase, in which the course structure was stabilized, learning outcomes were clarified, and the pedagogical model reached a repeatable and sustainable form.

Within this context, the Double Diamond model functions as a conceptual lens for interpreting the pedagogical evolution of GARM423 rather than as an instructional method. It enables the four iterations to be understood as components of a single, continuous design learning cycle, rather than as isolated curricular adjustments. This analytical framing reveals the course development as a systematic progression shaped by experimentation, reflection, and iterative refinement.

In conclusion, the Double Diamond model provides a robust theoretical foundation for articulating how GARM423 matured into its final form through design-based learning principles. The stabilized course structure that emerged from this process is examined in detail in the following section (*2.3 Final Course Design*), where the finalized timeline, materials, tools, and assessment strategies are presented.

2.3 Final Course Design: Plan, Materials, and Tools

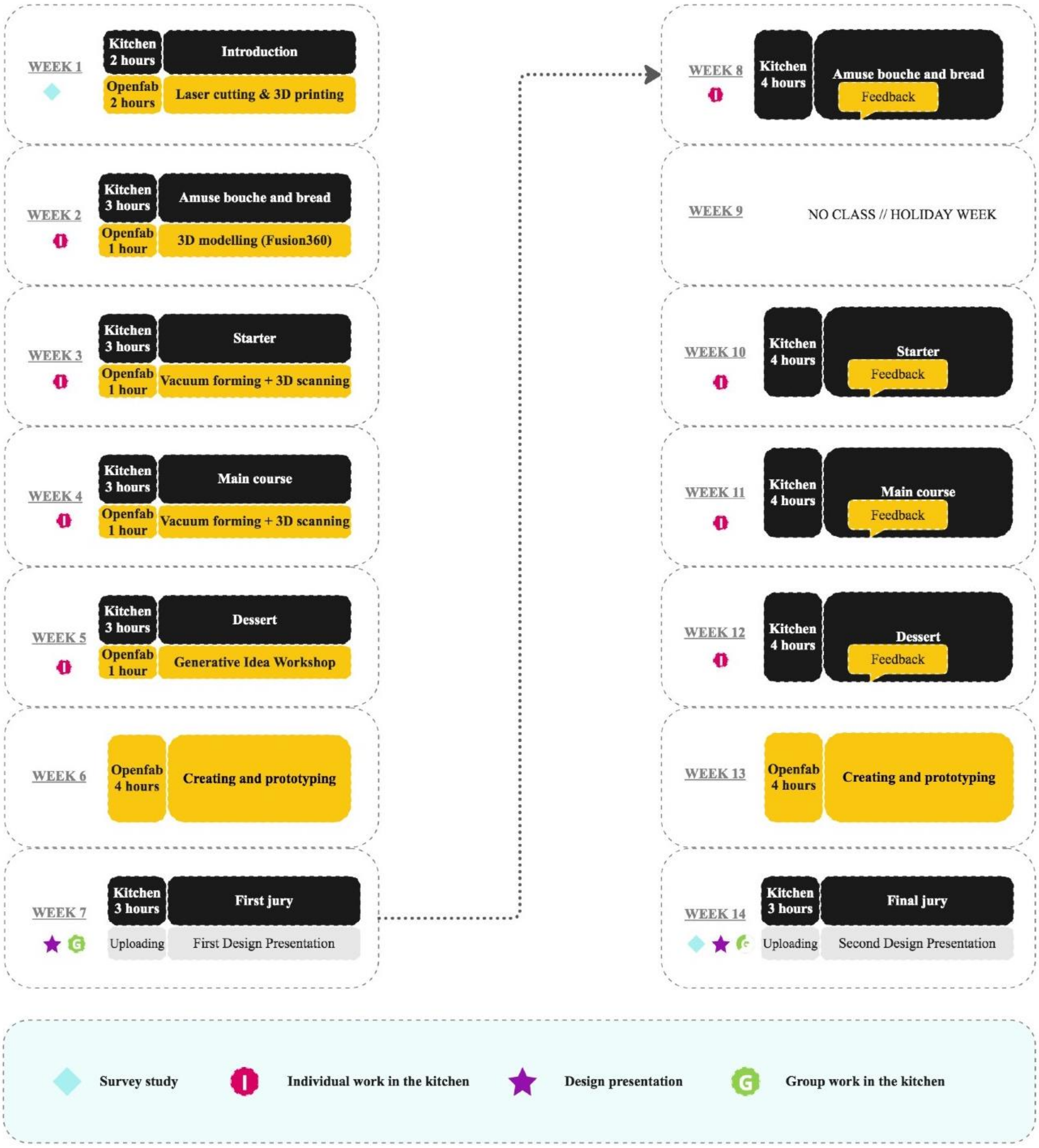
2.3.1 Course Timetable and Weekly Flow

The final iteration of the GARM423 course followed a fourteen-week structure that integrated studio-based practice, digital fabrication, and design-oriented learning within the field of gastronomy. Each week, the course met for a four-hour session that alternated between kitchen-based practice and Openfab activities. The weekly flow was reorganized based on insights gained from previous semesters, establishing a balanced structure between the professional kitchen (*Le Cordon Bleu*) and the digital fabrication laboratory (*Openfab*).

The first seven weeks of the course focused on introducing students to digital fabrication tools and materials, while the remaining seven weeks emphasized design development, prototyping, gastronomic applications, and final jury preparation. As noted by Coşkun and Baykal (2025), the course was structured in two interconnected phases: the first emphasizing design-based practices and jury preparation, and the second centering on prototyping and reflective production. Students were granted the freedom to choose the dish category *(i.e., amuse-bouche, starter, main course,* or *dessert)* that best aligned with their creative concepts. Throughout the semester, classroom observations, instructor feedback, and written notes were systematically collected and utilized as research data for the study.

The weekly structure of the final course iteration, outlining the progression of kitchen and Openfab activities, is presented in Figure 2.2.

Figure 2.2 *Weekly Course Schedule*



2.3.1.1 Week 1 - Introduction, Laser Cutting, and 3D Printing

The semester began with an introductory session covering the overall structure and objectives of the course, as well as examples of previous student works. Following the introduction to the kitchen workflow and technical guidelines, students participated in an Openfab orientation session. During this session, they were introduced to the laser cutter and 3D printer, learning basic operational principles and safety procedures through hands-on demonstrations. This early engagement helped students develop an initial awareness of how digital fabrication technologies can serve as creative tools in gastronomy.

2.3.1.2 Week 2 - 3D Modeling with Fusion 360

Before transitioning to asynchronous learning materials, students attended a *Fusion 360 Introduction Lesson* that covered the fundamentals of the software, including basic commands, dimension-based design principles, and precise drawing practices. This session provided essential preparation, allowing students to understand the logic of the software and enabling them to progress independently in subsequent weeks.

2.3.1.3 Week 3 - Vacuum Forming and 3D Scanning

In this class, students practiced using the vacuum forming machine to create molds from different objects, exploring the processes of forming and demolding. Instruction focused on key aspects such as draft angles, material behavior, and heat resistance, along with the operational logic of the machine. Collective discussions examined how vacuum-formed components could be integrated into culinary applications. Subsequently, students were introduced to 3D scanning technology and independently scanned selected objects, converting physical forms into digital data. Follow-up discussions emphasized how scanned models could be integrated into gastronomic product design, highlighting the advantages of 3D scanning for capturing complex geometries and natural textures.

2.3.1.4 Week 4 - Silicone Molding

This session focused on the preparation and techniques required for creating silicone molds. Students learned to construct mold walls around 3D-printed models using model-making materials and were introduced to methods for printing mold boundaries with the 3D printer. Oven-safe silicone samples with varying shore hardness values were examined, and discussions explored their use in design, prototyping, and culinary applications. Drawing from previous semesters, special emphasis was placed on controlling wall thickness and ensuring geometric precision in mold structures.

2.3.1.5 Week 5 - Generative Idea Workshop

Having acquired fundamental skills in computer-aided design and digital fabrication, students participated in a group-based *Generative Idea Workshop* to collaboratively develop innovative plate concepts. During this workshop, they synthesized aesthetic, sensory, and technological elements to propose original dish ideas. The session served as a critical learning stage, encouraging creative ideation, material discussion, and collective exploration of the tools and techniques introduced in earlier weeks.

2.3.1.6 Week 6 - Create Final Design

This week was conducted entirely in the *Openfab* environment. Prior to the first jury, students refined their digital designs in *Fusion 360*, received feedback from instructors, and finalized their production of molds, stencils, and other culinary tools. The session allowed them to consolidate their projects before the *First Design Presentation*, linking digital design processes directly with tangible gastronomic outcomes.

2.3.1.7 Week 7 - 12 - Iterative Design and Gastronomic Application

Following the first jury in Week 7, new ingredient lists were distributed for the development of final menus, and kitchen groups were reorganized. During this period, students focused on refining their prototypes and enhancing their dish designs through iterative experimentation. Working between the kitchen and *Openfab* spaces, they engaged in a continuous cycle of design iteration, material testing, and culinary integration (Figure 2.3). Under the guidance of instructors, students revised their designs, documented outcomes, and often continued their work outside scheduled class hours. The resulting prototypes were combined with culinary recipes developed in the kitchen, with outcomes informing subsequent design decisions.

Figure 2.3 *Images From Course Sessions Conducted in the Openfab*

2.3.1.8 Week 13 - Creating and Prototyping

In the week prior to the final jury, a full four-hour *Openfab* session was dedicated to finalizing digital models and physical prototypes. Students completed their last iterations in both software and fabrication, refining their designs in preparation for presentation. During this week, students also submitted their *Final Design Presentation* files, documenting their individual creative processes and production workflows.

2.3.1.9 Week 14 - Final Jury

The semester concluded with the final jury, in which student groups presented their innovative menus to a panel of chefs and instructors. Each student showcased their individual creative and technical development, reflecting on the relationship between digital fabrication and gastronomy. The stencils, molds, and other fabricated tools used in their dishes were exhibited alongside the plated presentations.

Throughout the semester, all sessions were systematically documented through instructor observations, field notes, and visual records of student prototypes. These materials were subsequently used as qualitative data for the analysis of the course's pedagogical outcomes.

In conclusion, the *Final Course* timetable established a mature equilibrium between structured technological instruction and open-ended creative exploration. The weekly sequence fostered a comprehensive learning process that progressed from foundational digital fabrication skills to independent creative applications, reinforcing an interdisciplinary studio model that interweaves design, technology, and gastronomy.

2.3.2 Digital Tools and Materials

In this research, the use of digital design and fabrication tools in gastronomy education was explored to encourage students' creative thinking, problem-solving, and experimental prototyping skills. The practices were conducted in the university's open production laboratory, where participants were actively involved both in kitchen-based and digital fabrication processes. This section provides a detailed explanation of the digital tools, production techniques, and materials used during the prototyping phase.

2.3.2.1 Digital Design and Fabrication Tools

Throughout the research, a range of digital tools were utilized to enable students to develop their design and fabrication competencies. These tools encompassed both computer-aided design (CAD) and digital fabrication processes (Figure 2.4).

Figure 2.4 *Digital Fabrication and Prototyping Tools Used During the Course*

Note. (a) Laser cutting, (b) 3D printing, (c) Vacuum forming, (d) Silicone molding, (e) 3D scanning.

Fusion 360 (Autodesk): All computer-aided design processes were carried out using this software. Students transitioned from initial hand sketches to digital modeling, adapting their designs to fabrication methods. In addition to the core functions of the program (dimensioning, 3D modeling, DXF file export), instructional videos were prepared and shared via Google Drive to support learning. Fusion 360 was used to prepare digital files for laser cutting and 3D printing, as well as to edit digital models obtained through 3D scanning.

Laser Cutter (Epilog Helix 24): The laser cutter, with a working area of 610×457 mm, was primarily used for stencil production. Designs completed in Fusion 360 were converted to DXF format for fabrication. Before final production, preliminary test cuts were performed on 80 g white paper, after which students evaluated and revised their designs. Final cuts were then produced using original materials such as Mayku sheets, PETG, and silicone sheets.

3D Printers (FDM Type): Devices from various brands, with build volumes ranging from 285×153×155 mm to 300×300×320 mm, were used during the study. Students employed PLA (Polylactic Acid) and TPU (Thermoplastic Polyurethane) filaments. PLA was selected for its high mechanical strength and environmentally friendly properties, while TPU was preferred for its flexibility and rubber-like structure, particularly suitable for mold making.

Vacuum Forming Machine (Mayku FormBox): Rapid mold prototyping was conducted using transparent thermoplastic sheets (Mayku Clear Sheet, 0.5 mm thickness, 210×210 mm dimensions). Students created vacuum-formed molds using either 3D-printed models or natural objects (e.g., seashells, pumpkins), transforming their digital designs into physical forms.

3D Scanner (MakerBot Digitizer): This device, capable of digitizing objects up to 203 mm in diameter and height at approximately 0.5 mm resolution, enabled students to transfer physical objects into CAD environments. Although only a few students utilized this technology, it provided valuable experience in physical-to-digital transformation. The scanner facilitated the rapid digitization of complex shapes that required advanced modeling skills.

These digital tools actively involved students in design and production processes beyond the kitchen, supporting the creation of molds, stencils, cutters, and presentation elements. While students were responsible for digital design and material selection, the Openfab team carried out the laser cutting and 3D printing processes. Students took an active role in vacuum forming and 3D scanning, guided by the researchers and the Openfab mentors.

2.3.2.2 Prototyping Materials

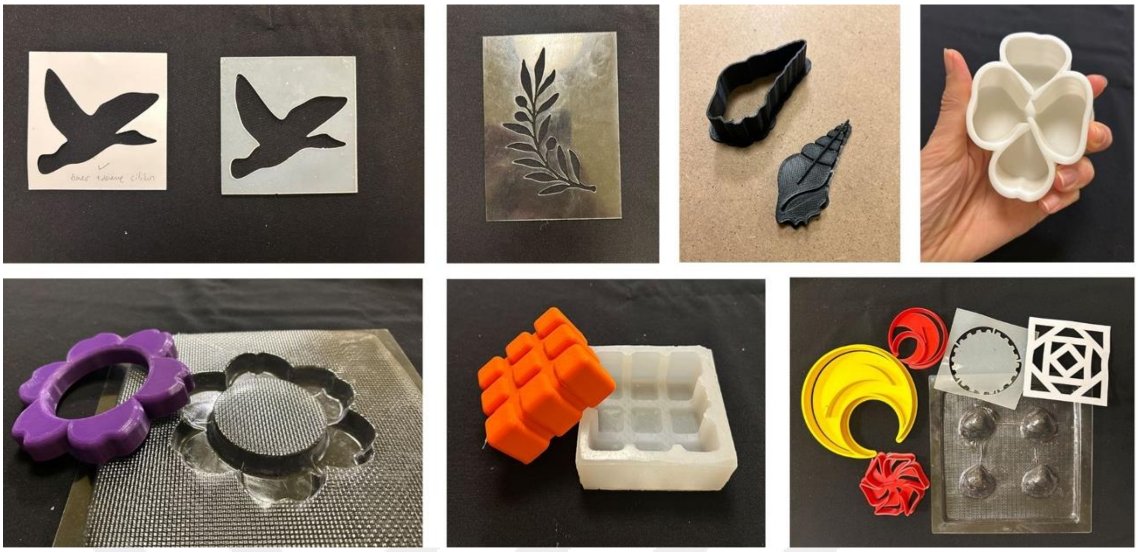
The materials used during prototyping were selected based on their compatibility with digital fabrication tools, food safety properties, and their diverse physical and form-giving characteristics.

- **Mayku Clear Sheet (0.5 mm, 210×210 mm):** A transparent thermoplastic sheet used for rapid vacuum forming and also utilized in stencil cutting via the laser cutter.
- **PETG Sheet (0.8 mm, 600×450 mm):** A durable and semi-flexible material used for laser cutting, serving as a thicker and sturdier alternative to the Mayku sheet during stencil production.

- **Silicone Sheet (1.5 mm, 180×180 mm):** Food-safe and oven-compatible silicone, produced by pouring into plexiglass molds. Due to its flexibility, it was primarily used for stencil fabrication.
- **Craft RTV2 Silicone (Shore 10, 15, and 20):** A two-component, food-grade silicone material used for producing oven-safe molds after a 24-hour curing period. Different Shore hardness levels were selected depending on the desired flexibility of the mold.
- **PLA and TPU Filaments:** The main materials used in 3D printing. PLA was preferred for rigid molds, while TPU was used for flexible and reusable molds.
- **Auxiliary Materials:** Supporting materials such as model cardboard, playdough, plexiglass sheets, glue, silicone gun, mixer, mixing bowl, and spatula were used during mold preparation and casting stages.

This diversity of materials allowed students to experiment with various textures, levels of flexibility, and durability. Material selection directly influenced aesthetic and functional design decisions, adding an experiential dimension to the learning process (Figure 2.5). Furthermore, material choice was treated as a design parameter shaping both the tactile and visual experience of the plate.

Figure 2.5 *Materials Used During the Prototyping Process and Sample Design Outputs*



Note. (a) paper and silicone sheet, (b) PetG, (c) 3D printing-PLA, (d) 3D printing-TPU, (e) 3D printing and vacuum mold, (f) 3D printing and silicone mold, (g) prototypes samples.

2.3.2.3 Fabrication Workflow and Experimental Approach

The digital fabrication process followed a cyclic model of design – prototyping – application – evaluation. Students first created digital models in Fusion 360, then produced initial prototypes using laser cutting or 3D printing techniques. After verifying the functionality, dimensions, and details of their prototypes, they proceeded to vacuum forming and silicone molding stages.

This iterative process enabled students to identify and address design errors experimentally. Consequently, the repetitive cycle strengthened their creative thinking, critical decision-making, and material-based learning skills. Ultimately, this approach demonstrated how digital fabrication can function as an effective pedagogical tool within an experiential learning model.

3. METHOD

This study was designed within the framework of Design-Based Research (DBR), an iterative and practice-oriented methodological approach that integrates the development of educational theory with real-world instructional interventions (Brown, 1992; Collins, 1992). In line with the principles of DBR, the research aimed to examine and refine the content design, educational framework, and implementation process of the GARM 423 course through multiple cycles of observation, documentation, and analysis. Ethical approval for the study was obtained prior to data collection (Ethics Committee Approval Code: 2024/18/07). Before participating in the study, all students were informed about the purpose, scope, voluntary nature of participation, and data usage procedures, after which written informed consent was obtained. Participation was entirely voluntary, and students who chose not to participate were excluded from the dataset. To ensure confidentiality and protect personal information, all identifiers were anonymized; students were coded as S1, S2, S3…, while chef participants were coded as C1, C2, C3… throughout the thesis.

The research followed a multi-phase methodological structure aligned with the iterative nature of DBR. In the first phase, a pre-survey was administered to examine students' prior knowledge, expectations, and technological readiness. In the second phase, the instructional intervention, centered on the integration of design-based activities and digital fabrication tools into gastronomy education, was implemented throughout the semester. During this phase, diverse forms of data were collected, including individual design presentations, student outputs, production processes, and kitchen jury observations, to document students' ongoing development. In the third phase, semi-structured interviews with students and chefs, as well as a focus group session, were conducted to obtain deeper insights into how participants experienced the integration of design and technology in practice. Each data collection method served a complementary purpose: surveys captured perceptual and experiential change, student presentations documented process-based learning, jury sessions revealed group-level decision-making and applied practice, and interviews provided reflective and experiential perspectives. This multi-layered approach enabled a rich triangulation of data and supported a comprehensive evaluation of the course design, its implementation, and its impact on students' learning processes.

3.1 Data Collection

3.1.1 Surveys With Students

Two sets of surveys were conducted to collect both quantitative and qualitative data regarding students' learning experiences and competencies in the GARM 423 Culinary Exhibitions and Seminars course. The aim of these surveys was to evaluate how students developed their creative thinking, technological literacy, and professional awareness throughout a design-based gastronomy education process that integrated digital fabrication tools. The surveys were conducted at two stages of the semester to capture changes in students' experiences and perceptions: a pre-survey administered during the first week and a post-survey conducted in the final week of the course. Both surveys were administered online through Google Forms, and participation was voluntary. Students were invited to provide their names and email addresses if they agreed to be contacted for follow-up interviews to allow for deeper examination of the data.

The pre-survey consisted of four questions designed to identify students' prior experiences and familiarity with digital design and fabrication tools, their expectations from the course, and their future career goals related to the integration of design and technology in gastronomy. It explored their previous exposure to technologies such as 3D printing, laser cutting, vacuum forming, silicone molding, and 3D scanning, as well as their prior experience in designing molds or templates. Students were also asked to express their expectations from the course and how they envisioned using design and technological skills in their future professional practice. This initial survey provided a baseline for understanding students' readiness, motivation, and awareness regarding the integration of design and technology into culinary education (See Table 3.1 for the full questionnaire).

Table 3.1 *Overview of Pre-Survey Questions and Analytical Dimensions*

Question No	Question	Question Type	Intended Purpose
Q1	Have you ever used any digital fabrication tools before (e.g., 3D printer, laser cutter, vacuum former, silicone mold)?	Multiple choice	Determine whether students have previously used digital tools and production technologies.
Q2	Have you ever designed your own molds, stencils, or cutters before?	Dichotomous (Yes/No)	Determine whether students have prior practical experience in designing the specified products.
Q3	How do you plan to use the experiences and knowledge you will gain from the course activities in your professional career?	Open-ended	To explore students' perceived transfer of learning - how they anticipate applying design and technology-based skills to their future professional practice in gastronomy.
Q4	Would you like to share any comments, questions, or feedback regarding the course program?	Open-ended	To collect participants' reflections, feedback, and suggestions to support formative evaluation and curriculum improvement.

The post-survey, conducted during the final week of the semester, consisted of ten questions that combined multiple-choice, Likert-scale, and open-ended items. It aimed to assess students' learning outcomes, experiences, and perceptions after completing the course. Specifically, the questions focused on:

- The types of digital tools and fabrication techniques students used during their individual projects (e.g., laser cutting, 3D printing, vacuum forming, silicone molding);
- Their self-assessment of difficulty levels across various stages of the design and production process (i.e., idea generation, 3D thinking, CAD modeling, integration into food preparation);
- Their reflections on challenges, successes, and material experimentation;
- Their evaluation of how these tools contributed to creativity, collaboration, and problem-solving; and
- Their perceived competence and confidence in applying design and technology skills in future gastronomy careers.

Through these questions, the post-survey provided a comprehensive overview of students' overall development during the course from initial curiosity to applied technological proficiency (see Table 3.2 for the full questionnaire).

Table 3.2 *Overview of Post-Survey Questions and Analytical Dimensions*

Question No	Question	Question Type	Intended Purpose
Q1	Which tools did you use during your individual design production process? (Multiple selection: Laser cutter, 3D printer, 3D scanner, Vacuum	Multiple choice	To identify which digital fabrication tools students used during their individual production processes.

Question No	Question	Question Type	Intended Purpose
	forming, Silicone molding, None, Other)		
Q2	How would you evaluate your individual process in the following areas? (1–Very Difficult, 2–Difficult, 3–Somewhat Easy, 4–Easy, 5–Very Easy)	Likert scale (1–5)	To assess students' perceived difficulty levels generating new ideas,three-dimensional thinking, computer-aided design,transferring designs to a computer environment, understanding production methods,developing designs and integrating into the cooking process.
Q3	Would you like to share any specific experiences related to any of these processes?	Open-ended	To gather qualitative insights about students' personal reflections and challenges during the production process.
Q4	Please choose your experience with the following tools throughout the course (before–during–after): stencil, cutter, silicone mold, vacuum mold, 3D printed mold.	Multiple choice	To understand students' evolving experiences with different fabrication tools and materials across the learning stages.
Q5	Please share your positive experiences during the learning process.	Open-ended	To identify factors that contributed positively to students' motivation and engagement.
Q6	Please share your negative experiences during the learning process.	Open-ended	To identify challenges and difficulties encountered during the course for future curriculum improvement.
Q7	Do you plan to use the design tools and technological skills you learned in this course in your gastronomy career?	Open-ended	To explore students' intentions to transfer learned design and technology competencies into professional practice.
Q8	After this course, how competent do you feel in applying new technologies in the field of gastronomy?	Likert scale (1–5)	To evaluate students' self-perceived technological competency and confidence in applying new technologies.

Question No	Question	Question Type	Intended Purpose
Q9	After this course, how competent do you feel in applying design-related skills in the field of gastronomy?	Likert scale (1–5)	To evaluate students' confidence in applying design-oriented learning outcomes in professional contexts.
Q10	Do you have any additional feedback, ideas, or reflections you would like to share with us?	Open-ended	To collect final reflections, suggestions, or comments about the course experience and content.

A total of 29 undergraduate students (aged 18–24) enrolled in the course participated in the study. A total of 27 students (22 female, 5 male) participated in the pre-survey, while 23 students (20 female, 3 male) completed the post-survey. The two surveys together captured students' transformation throughout the design-based learning process, examining creativity, technological adaptation, self-efficacy, and professional awareness.

3.1.2 Evaluation of Student Works and Jury Sessions

3.1.2.1 Student Processes and Individual Outputs

Within the scope of the GARM 423 Culinary Exhibitions and Seminars course, two structured presentation templates titled *First Design Presentation* and *Second Design Presentation* were prepared to document the individual processes and design developments of each student. Students were asked to fill out these templates throughout the semester to record their design sketches, product prototypes, iterations, and results from kitchen applications. In addition, students presented and defended their group projects at the end of the semester during the *Kitchen Jury* sessions, where their final dishes and plate designs were evaluated by a panel of chefs and instructors. However, not all individual design and prototyping outcomes were included in these jury sessions.

Therefore, separate documentation formats were developed to record individual and group projects independently, ensuring that the iterative design process of each student could be assessed in its entirety. During the course, three main sources were used to collect student outputs: *First Design Presentation*, *Second Design Presentation*, and *Kitchen Jury* sessions.

The *First Design Presentation*, conducted in the seventh week of the semester, aimed to document students' initial design ideas, production methods, and recipe concepts developed during the early stages of the course. Each student individually presented their first sketches, design intentions, and reflections by responding to three guiding questions about the production methods they planned to use (e.g., stencil, 3D printing, silicone molding), the stage of the cooking process in which the design would be applied (e.g., shaping, decoration, or preparation), and the dish and recipe where the design would be integrated. The detailed structure and question set of the *First Design Presentation* template can be found in Table 3.3.

Table 3.3 *First Design Presentation Template and Questions*

Photos: Sketch or prototype	Q1. What methods do you plan to use to produce your designs?
	Q2. In which part of the cooking process do you intend to use your design?
	Q3. Can you explain the dish you will use the mold you designed? Give information about recipe.

These early presentations provided insight into students' initial creative thinking and their ability to connect digital fabrication techniques with culinary applications. They also encouraged students to refine their design practices, experiment with prototyping methods, and prepare for the upcoming kitchen jury sessions.

The *Second Design Presentation*, carried out in the fourteenth week, aimed to capture the complete development of students' projects from initial concept to final culinary integration. At this stage, students presented how they revised, tested, and implemented their designs while reflecting on the knowledge and skills gained throughout the process. The presentation template was divided into four main sections: Stencil Design, 3D Printing, Molding, and Final Plate Design. The detailed presentation structure and guiding question set used in the *Second Design Presentation* template are provided in Table 3.4.

Table 3.4 *Second Design Presentation Template and Questions*

Stencil design and produce	Page: 1
Photos of stencil	Photos of applied stencil
Q1. Have you changed or improved your design/draw? Why did you need it?	***Q2. What did you learn during the stencil design and application process?***
3D printing design and produce	Page: 2

Photos of 3D printing	Photos of applied 3D printing
Q3. Have you changed or improved your design/draw? Why did you need it?	***Q4. How did you plan to use it in the food preparation process?***
Mold design and produce (Vacuum or silicone)	Page: 3
Photos of mold	Photos of applied mold
Q5. Have you changed or improved your design/draw? Why did you need it?	***Q6. What kind of recipe would you like to use in this mold?***
Final plate design	Page: 4
Photos of sketch	***Q7. How will you combine what you have learned with your recipe?Describe your final design!***
	Q8. Which methods and design will you use for your final meal?

These included documentation of prototypes produced using laser cutting, 3D printing, vacuum forming, or silicone molding, as well as photographic evidence of the iterative processes and their culinary applications. The final section presented the selected or reinterpreted designs prepared for the kitchen jury, showcasing how students synthesized their learning in design, technology, and gastronomy. Collectively, these presentations provided comprehensive visual and textual evidence of students' design iteration, problem-solving, and integration of digital fabrication tools into their culinary practice.

This study also utilized structured presentation templates to ensure consistency in the documentation of student works. Each template included specific guiding questions designed to capture the development of students' design thinking, technical processes, and creative integration throughout the semester. The question sets were standardized across the *First* and *Second Design Presentations* to enable comparative evaluation between the early and final stages of the course.

The *First* and *Second Design Presentations* together provided a systematic record of students' individual progress in terms of both creative development and technical competence. These documents served as primary data sources in assessing how students engaged in the design-based learning cycle (including idea generation, prototyping, testing, and refinement) within the context of gastronomy education.

3.1.2.2 Jury-Based Evaluation of Student Outputs

The jury presentations consisted of two stages: a first jury and a final jury, both conducted during the semester. The kitchen juries aimed to evaluate the group-based practical projects carried out by the students. The first jury was held in the seventh week, while the second one took place in the fourteenth week of the semester.

In the first kitchen jury, students were free to present a new template or mold design. This jury primarily provided students with an opportunity to apply what they had learned since the beginning of the semester and to improve their practical skills. In contrast, during the final jury held in the fourteenth week, each group was expected to include at least one new mold or design element in their menu. This process allowed for the assessment of students' ability to transition from individual design development to group-based practice and to integrate design outcomes into the gastronomic context.

The jury presentations were conducted at the group level, and students collaboratively presented their menu designs based on collective decisions. Following a three-hour preparation period in the kitchen, each group presented their design prototypes, menu outputs, and the corresponding dishes that incorporated these designs for evaluation by the jury members. The evaluation process was carried out by two professional chefs and one researcher, in addition to the chef responsible for the GARM 423 course. The jury members assessed the student projects according to standard culinary jury criteria, such as presentation, taste, technical execution, and time management, alongside a specific criterion developed for this research, which focused on the use and integration of design molds within the dishes. In addition, four main categories (i.e., technique, creativity, presentation, and flavour and taste) were used as standard evaluation dimensions, while an extra category, mold project application, was included to evaluate the integration of design-based outputs into the culinary work.

Throughout the jury sessions, menu photographs, student presentation materials, and researcher observation notes were collected as qualitative data. These jury sessions served as a meaningful data source for analyzing how individual design outcomes were reshaped through group decisions, how digital fabrication tools were integrated into gastronomic production processes, and how teamwork influenced the resulting design outcomes.

3.1.3 In-Depth Interviews With Students and Chefs

At the end of the semester, semi-structured one-on-one interviews were conducted with students and chefs to explore how the integration of digital fabrication tools into gastronomy education was perceived and evaluated by both groups. These interviews were designed to deepen the findings of the survey study and to obtain qualitative insights into participants' learning experiences. Separate question sets were prepared for students and chefs. All interviews were conducted on a voluntary basis.

3.1.3.1 Interviews With Students

At the end of the semester, 13 students (11 female, 2 male) participated in individual interviews. These interviews focused on students' reflections on their design-based learning experiences, use of digital fabrication tools, and the processes they followed throughout the course. Each interview lasted approximately 15 minutes and was conducted in the participant's preferred language (Turkish or English). The interviews aimed to understand the challenges students faced during the learning process, the improvements they made to their design practices, and how they integrated technology into gastronomic production. The main questions addressed in the student interviews are listed below:

Q1. Could you describe your process of finding new ideas and developing your designs?

Q2. How did the processes of design, production, and food preparation progress?

Q3. Did you make any improvements to your designs? Why were these improvements necessary?

Q4. What challenges did you encounter during the process?

Q5. What were the most enjoyable experiences for you during the course?

Through these interviews, students' creative thinking approaches, collaborative experiences, and relationships with technology were analyzed to understand their impact on learning processes.

3.1.3.2 Interviews With Chefs

Individual interviews were also conducted with three professional chefs who led the kitchen courses for different student groups. Information on their gender, age, professional experience, and area of expertise is provided in Table 3.5. Each interview lasted approximately 15 minutes and was conducted in the participant's preferred language. These interviews aimed to understand how the integration of digital fabrication tools into gastronomy education was evaluated from a professional perspective, examine the instructors' experiences, and analyze how students' design-based competencies were reflected in professional practice. The questions addressed in the chef interviews are summarized below:

Q1. Did you design your own stencils, cutters, or molds? Why did you feel the need to do so?

Q2. Which tools did you use during the design and production process? Could you share your experience?

Q3. Were there any challenges in integrating gastronomy, design, and technology?

Q4. How do you think students' design and technological competencies contribute to their professional development?

Q5. Are there differences between professional tools and the ones you or your students designed? Could you elaborate?

These chef interviews provided valuable insights into the interaction between design, technology, and production processes in applied gastronomy education and offered a professional perspective on how students' acquired skills are reflected in the culinary field.

Table 3.5 *Demographic and Professional Profile of the Chefs*

Participants	Gender	Age	Years of Experience	Area of Expertise
Chef 1 (C1)	Male	47	30	French, Italian, and Spanish cuisine
Chef 2 (C2)	Male	65	49	French cuisine
Chef 3 (C3)	Male	65	40	Hot kitchen and pastry

3.1.4 Focus Group With Students and Chefs

A focus group session was conducted with students and chefs who had experienced the integration of design practices and digital fabrication tools within the GARM 423 "Culinary Exhibitions and Seminars" course. This session aimed to complement the individual interviews by providing a collective setting in which participants could reflect on and discuss their shared experiences throughout the course. The focus group method was employed as a qualitative data collection technique that emphasizes group interaction and shared reflection (Krueger & Casey, 2015).

At the beginning of the session, participants were invited to introduce themselves and share their prior experiences related to the integration of gastronomy, design, and technology. The session was conducted with four students enrolled in the course and three chefs who taught or contributed to it, lasting approximately 60 minutes. The discussion was moderated by the researcher, and the entire session was audio-recorded while field notes were taken to support subsequent analysis.

The four student participants were actively involved in the course throughout the semester, taking part in all stages of the process, including design development, prototyping, and jury presentations. Four chefs were expected to participate in the focus group, but one chef did not attend the meeting. Two of the participating chefs were responsible for conducting kitchen practice sessions with different groups of students, while the third was one of the chefs who participated in the jury evaluations for the GARM 423 course throughout the semester.

The chefs' experiences varied considerably:

- Chef 1 completed the digital modeling of the molds needed for his plated dishes, producing them using several prototyping techniques such as 3D printing, laser cutting, and silicone molding, and later integrated these outputs into his culinary creations.
- Chef 2 designed sketches and dimensions for molds required during food service. These sketches were digitally modeled by the researchers to prepare the necessary fabrication files for production.
- Chef 3 was not directly involved in the teaching process but participated as an observer during the jury sessions. Based on shared videos and discussions with the researchers, he developed his own digital drawings in Fusion 360 and produced them using 3D printing technology.

During the session, both students and chefs reflected on their learning experiences, the challenges they encountered, and the relationship between these activities and gastronomy education. The discussion revolved around two central guiding questions:

1. *What approaches and processes did you follow in the integration of design, technology, and gastronomy?*

2. *What are the potential implications of these learning experiences for gastronomy education and professional practice?*

This session provided valuable insights into the collective perception of design- and technology-oriented learning in gastronomy education and offered qualitative data for understanding the interactions among different roles (students, chefs, and researchers) as well as the interdisciplinary forms of collaboration that emerged during the course.

3.2 Data Analysis

3.2.1 Analytical Approach

The data analysis in this study followed a mixed-method approach, integrating both quantitative and qualitative analyses to examine how design-based learning practices influenced students' creative and professional development in gastronomy education. The analytical framework was structured within the Design-Based Research (DBR) methodology, allowing an iterative relationship between data collection, reflection, and design intervention. This approach enabled the identification of evolving learning patterns, the integration of digital fabrication technologies into culinary practice, and the evaluation of educational outcomes across multiple datasets.

In the quantitative dimension, survey data (pre- and post-surveys) were analyzed through descriptive statistics, including frequency, percentage, and mean distributions. These results provided an overview of changes in students' self-perception, creativity, and professional awareness throughout the course. In the qualitative dimension, thematic analysis and qualitative content analysis were employed to interpret open-ended responses, interviews, design presentations, and jury evaluations. In line with the principles of DBR, this study employed multiple data sources and iterative cycles of analysis, supported by methodological triangulation to enhance the trustworthiness of the findings (Denzin, 1978).

The overall process was iterative and reflexive, reflecting the cyclical nature of DBR. Each phase of analysis informed the subsequent design and evaluation stage. Data from surveys, design presentations, interviews, and jury sessions were continuously compared to capture how students developed creative competencies and adapted digital tools to culinary design.

Figure 3.1 presents an overview of all datasets used in the study, including the number of participants, gender distribution, and timing of each activity. This table illustrates how data collection was distributed across the semester, supporting both the quantitative and qualitative components of the analysis.

Figure 3.1 *Overview of Data Collection by Type, Number of Participants, and Timing*

TYPE	QUESTIONS	NUMBER OF PARTICIPANTS	GENDER	WEEK
Pre-survey	4	27	22 Female / 5 Male	1st
Juries	-	27	22 Female / 5 Male	7th - 14th
First Design Presentation	3	27	22 Female / 5 Male	6th
Second Design Presentation	10	28	22 Female / 6 Male	14th
Interview with students	5	13	11 Female / 2 Male	15th
Interview with chefs	5	3	3 Male	15th
Post-survey	10	22	18 Female / 4 Male	14th
Focus group	2	7	3 Female / 4 Male	16th

3.2.2 Analysis I: Thematic Analysis of Design Integration in Culinary Education

The thematic analysis in this study was conducted in line with the reflexive thematic analysis approach proposed by Braun and Clarke (2019) and Byrne (2022). The coding process began with a close reading of the data and was carried out in a fully inductive (data-driven) manner.

At the first stage, pre- and post-survey data were compiled in Excel. Open-ended responses reflecting students' expectations before the course and their learning outcomes after the course were systematically arranged. In particular, pre-survey (Q3) and post-survey questions (Q3, Q4, Q5, Q7) were the primary focus of the analysis. Statements obtained from these responses were transferred to Miro boards, where digital post-it notes were used to cluster similar or conceptually related expressions.

From these clusters, initial codes were generated. The codes were then transferred onto physical post-it notes, which enabled the researcher to visually reorganize and refine them through multiple iterations. Similar codes were merged, while those with overly broad or narrow scopes were redefined. The process followed a four-stage iterative cycle, after which the established themes and corresponding responses were consolidated within Excel.

At the end of this phase, four main themes and six sub-themes were identified. This structure was later expanded with additional data from student interviews (Q1, Q3, Q4, Q5) and chef interviews (Q1–Q5). In total, five review cycles (iterations) were conducted: four simultaneously on Miro and physical post-it boards, and a final review in Excel to verify thematic consistency. During the second phase, when interview data were integrated, three additional reviews were conducted to refine sub-theme definitions, particularly under Theme 3: Developing New Competencies.

The coding process was jointly undertaken by the researcher and the supervisor. Throughout the analysis, reflexive notes were maintained to document analytical decisions and reflections. Transitions between codes and themes were continuously compared with the main research questions, ensuring analytical coherence across all iterations. This approach followed Braun and Clarke's (2019) emphasis on the transparent acknowledgment of the researcher's interpretive position within the analysis.

The semi-observation notes were actively utilized in both Phase 1 and Phase 2. These notes helped connect students' behavioral observations with their qualitative reflections and supported thematic interpretation, particularly in relation to creative problem-solving practices observed throughout the course. Table 3.7 summarizes the data sources, analytical tools, and the evolution of the thematic structure across the two phases. In Phase 1, only survey and observation data were analyzed, whereas in Phase 2, student and chef interviews were added, allowing the themes to deepen and expand. Coding in both phases was conducted using Excel and Miro, with the analysis shifting from a purely inductive approach in Phase 1 to a semantic–inductive orientation in Phase 2. Furthermore, the data sources that contributed to the formation of each theme are presented in Table 3.6. This table illustrates how each theme was supported by multiple datasets (surveys, interviews, and observations), thereby reflecting the study's implementation of the triangulation principle.

Table 3.6 *Summary of Data Collection Components and Analysis Frameworks Across Phase 1 and Phase 2*

Component	Phase 1	Phase 2
Data Collection	Pre-survey (Q3) Post-survey (Q3, Q5, Q6, Q7) Student interview (Q1, Q3, Q4, Q5) Chef interview (Q1-Q5) Semi-structured observation	Pre-survey (Q1) Post-survey (Q2, Q4, Q8, Q9, Q10) Student interview (Q1, Q3, Q4, Q5) Chef interview (Q1-Q5) Semi-structured observation
Tools	Excel + Miro + Post-it notes	Excel + Miro
Thematic Structure	4 main themes with 6 sub-themes	4 main themes with 8 sub-themes
Type of Analysis	Inductive	Semantic inductive

The development of themes was carried out through a two-stage thematic analysis, aligned with the iterative structure of the DBR framework. The thematic analysis was conducted in two stages, following the iterative structure of the DBR framework. In Phase

1, the thematic structure was developed inductively using both qualitative and quantitative data gathered from students and chefs, with the researcher identifying recurring patterns across survey responses, interview insights, and observational notes. These patterns informed the initial coding process, and the resulting codes were consolidated into four main themes: Creativity and Innovation in Culinary Design, Challenges about the Process, Developing New Competencies, and Feeling Prepared for the Future. Each theme emerged directly from participants' reflections rather than from predefined categories, ensuring that the analytical process remained grounded in the data itself.

In Phase 2, with the expansion of the dataset, particularly through post-survey responses and deeper interview insights, Theme 3: Developing New Competencies was revisited. Two new sub-themes were identified under this theme: Acquiring New Technical Skills and Building Confidence and Self-Awareness. The emergence of these sub-themes indicates that students' engagement with digital fabrication technologies led not only to technical growth but also to cognitive and emotional transformation. This development corresponds to the process of "theme refinement" described by Braun and Clarke (2019) within reflexive thematic analysis. Accordingly, the themes were reshaped based on data-driven insights, representing new meaning patterns that emerged through successive cycles of the design-based learning process.

Following the completion of Phase 2, the data groups that contributed to the formation of the sub-themes under each main theme are presented in Table 3.7. This table outlines the specific datasets (surveys, interviews, and semi-observations) that played a role in shaping each thematic category and further demonstrates the triangulation approach applied throughout the analysis.

Table 3.7 *Themes and Associated Datasets Used in the Thematic Coding Process*

Theme 1: Creativity and Innovation in Culinary Design		***Theme 2: Challenges about the Process***
Pre-survey	Q1 - Q3	-
Post-survey	Q1 - Q3	Q2- Q3 – Q5 – Q6 – Q8- Q9
Student interview	Q1	Q4 – Q5
Chef interview	Q1 – Q2 – Q5	Q3 - Q4 - Q5
Theme 3: Developing New Competencies		***Theme 4: Feeling Prepared for the Future***
Pre-survey	Q1 - Q3	Q1
Post-survey	Q3 - Q4 - Q5 - Q6 - Q7 - Q8 - Q9	Q4 - Q7 - Q8 - Q9 - Q10
Student interview	Q4 - Q5	Q3 - Q4 - Q5
Chef interview	Q4	Q4 - Q5

3.2.3 Analysis II: Content Analysis of Student Outcomes and Processes

This content analysis aimed to examine, in an integrated manner, the outputs developed by students throughout the design-based learning process, their use of digital fabrication tools, and the data obtained from jury evaluations. The analysis was structured around three main categories: (1) Design-Based Practices, (2) Prototyping Processes Using Digital Fabrication Tools, and (3) Jury Outcomes. These three categories were defined at the outset of the study as a general analytical framework; however, as the data collection process progressed, sub-themes were refined and deepened through insights drawn from the students' individual processes. This approach aligns with the principle emphasized by Schreier (2012) and Krippendorff (2018) in qualitative content analysis, which allows predefined categories to expand in a data-driven manner.

In this analysis, multiple data sources were considered together. The First Design Presentation (FDP) was completed individually by 27 students, while the Second Design Presentation (SDP) was completed by 28 students. Two major jury sessions were held throughout the semester: the First Jury (Week 7) and the Final Jury (Week 14). During these sessions, students presented their dishes and design processes in groups. The dataset consisted of PowerPoint presentation files, prototype visuals, survey results, researcher field notes, and transcripts from interviews. A total of 13 volunteer students participated in in-depth interviews, which enriched the qualitative dimension of the analysis. Jury sessions were further supported by researcher observations and semi-observation notes collected throughout the course. The datasets, question scope, and supporting datas used in the content analysis are summarized in Table 3.8. This table provides an overview of all data sources analyzed within this phase, including individual design presentations, interviews, and group-level jury evaluations. It demonstrates how qualitative and quantitative data were triangulated across the design-based learning process, showing the connections between student outputs, observational records, and the corresponding research questions that guided the analysis.

Table 3.8 *Overview of the Data Sources,Themes and Associated Datasets Used in the Thematic Coding Process*

Data Source	Participants	Outputs / Focus	Question Scope	Supporting Data
First Design Presentation (FDP)	27 Students	Individual design presentations and ideation	Q1 – Q2 – Q3	Semi-structured observation notes
Second Design Presentation (SDP)	26 Students	Individual design presentations and prototyping outcomes	Q1 – Q2 – Q3 – Q4 – Q5 – Q6 – Q7 – Q8 – Q9 – Q10	Researcher notes

Data Source	Participants	Outputs / Focus	Question Scope	Supporting Data
Interview with students	13 Volunteer students	Individual experiences and reflections on design process	Q1 – Q2 – Q3 – Q4 – Q5	-
Jury sessions	27 Students – 8 Group menus and 32 dishes	Collective presentations of final dishes and group evaluations	First and final jury	Researcher notes, photographs

The content analysis process was designed to explore how students learned and produced during the integration of design-based approaches into culinary education. Three primary codes, Design Practices, Prototyping with Digital Fabrication Tools, and Jury Outcomes, were established at the beginning of the process. As the analysis deepened, these categories evolved into a total of 11 sub-themes. The main themes were revised and expanded without losing their initial conceptual intent. The final themes were: (1) Design-Based Practices & Evolution of Creative Processes, (2) Integration of Digital Fabrication into Culinary Practices, and (3) Integrated Learning Outcomes Supported by Jury Performance. Sub-themes naturally emerged from the diversity of the datasets (surveys, presentations, interviews, and jury notes). For instance, the sub-theme Design Flow Models in Gastronomy Integration under Theme 1 was derived from the combination of students' process explanations and the design-flow diagrams presented in their files. Similarly, the unplanned sub-theme Cross-Method Integration in Single Plate under Theme 3 originated from students' efforts to merge multiple digital fabrication techniques within a single dish presentation.

Coding was performed using Miro and Excel, combining digital and physical materials. The text and visuals from presentation files were transferred into Excel spreadsheets, while interview transcripts (Q1–Q5) were represented as digital post-it notes on Miro. The coding was conducted collaboratively by the researcher and the supervisor, ensuring consistency in meaning and thematic coherence at each stage. The unit of analysis was defined as a holistic representation of each student's complete design process. Accordingly, survey responses, presentation files, jury evaluations, and semi-observation notes were treated collectively as a single case within the analysis.

The analytical focus of the content analysis was structured around the students' individual development processes and outputs across three major themes:

A. Design-Based Practices & Evolution of Creative Processes: This theme examined how students generated new ideas, progressed through stages of design and prototyping, and articulated each step of their creative process. The analysis emphasized students' approaches to originality, problem-solving strategies, and iterative improvements that led to distinctive design flows.

B. Integration of Digital Fabrication into Culinary Practices: This theme explored how students integrated digital fabrication technologies into culinary contexts. Techniques such as laser cutting, 3D printing, vacuum forming, silicone molding, and 3D scanning were analyzed in terms of their frequency, variety, related challenges, and contribution to creative expression.

C. Digital Fabrication Outcomes in Student Outputs: This theme focused on the technical, aesthetic, and conceptual qualities of the students' final outcomes as presented during the jury sessions. The analysis considered factors such as the number and variety of molds used, their functional fit with the dishes, and how different prototyping techniques were combined within a single presentation. Moreover, the influence of mold integration on technical skill, creativity, presentation quality, and taste was examined as part of the content analysis.

Qualitative responses to open-ended questions were thematically analyzed, while quantitative data from multiple-choice and Likert-scale questions were interpreted through frequency comparisons. Numerical data, such as the number of digital tools used in prototypes, the diversity of templates, and mold-integration ratios, were coded and compared with survey findings. Instances where students emphasized issues in interviews that were absent from their survey responses were also examined contextually and are discussed further in the Results section.

Visual and documentary materials such as process presentations, prototype images, final-dish photographs, and design-flow diagrams were used as visual data sources, supported by interview transcripts and semi-observation notes. Chef interviews were not included in this stage of analysis, as the primary aim here was to reveal students' individual transformations within the design-based learning process and the evolution of their creative outputs.

3.2.4 Analysis III: Thematic Analysis of Focus Group Perceptions of Design Integration in Culinary Education

The focus group data were analyzed using Braun and Clarke's (2006, 2019) reflexive thematic analysis approach, following a fully inductive orientation. To ensure methodological consistency with the earlier thematic analysis section of the study, the process was structured in two stages; Phase 1 and Phase 2. The focus group consisted of three chefs and four gastronomy students. Rather than adhering to the sequence of interview questions, the analysis centered on identifying patterned meanings within participants' narratives.

3.2.4.1 Phase1: Initial Coding and Development of the Preliminary Thematic Structure

In Phase 1, the focus group transcript was read multiple times, and coding was conducted by the researcher using both digital tools (Excel) and manual techniques. Codes were generated directly from the data, with participants' statements segmented into meaningful units and transformed into open codes. Similar codes were grouped, differing perspectives were distinguished, and preliminary data-driven patterns were identified.

Phase 1 focused primarily on responses to the first interview question, which generated a rich and detailed dataset regarding participants' experiences with the design process. This initial coding stage resulted in over 40 open codes, which were subsequently organized into early thematic clusters. These clusters captured patterns related to sources of inspiration, workflow dynamics, technical learning challenges, and functional design decision-making. Without applying any predefined structure, six preliminary themes were constructed based solely on natural data-driven clustering, forming the foundation for later refinement.

3.2.4.2 Phase 2: Deepening, Reorganizing, and Integrating Themes

In Phase 2, responses to the second interview question were analyzed and compared with the coding and thematic structure derived from Phase 1. In this phase, participants focused on issues such as the long-term effects of learning new technologies, projections about their professional futures, and the transformative potential of design-oriented thinking within gastronomy.

New open codes were produced and compared with the initial coding set. Through merging, renaming, reorganizing, and further abstraction, themes were restructured to strengthen analytical coherence. Boundaries between themes were reassessed, and relationships between codes and themes were clarified.

3.2.4.3 Finalization of the Thematic Structure

During the refinement process, the six preliminary themes from Phase 1 were partially merged, reorganized, or redefined in terms of scope. By the end of Phase 2, the thematic structure was consolidated into four main themes, each supported by two sub-themes. This resulted in a more coherent and analytically robust thematic framework.

Across the entire process, at least two full coding cycles and two thematic refinement cycles were completed. As all codes were generated manually by the researcher, reflexive thematic analysis principles were closely followed; the researcher's interpretive stance was explicitly acknowledged, and reflexive analytic notes were maintained throughout the code–theme transitions.

Because the focus group data were exclusively qualitative, triangulation was not employed. Nevertheless, the two-phase structure enabled a comprehensive examination of the data both horizontally (across questions) and vertically (from codes to themes). The integrated analysis of Phase 1 and Phase 2 ultimately yielded four main themes presented in the Results chapter: (1) Understanding Meaningful Gastronomic Design, (2) Design Process and Creative Production Dynamics, (3) Technical Learning Experience and Adaptation to Production, (4) Future Perspectives and Professional Transformation in Gastronomy.

4. RESULTS

4.1 Findings From the Thematic Analysis of Surveys and Interviews

This thematic analysis was conducted using data obtained from pre- and post-course surveys alongside semi-structured interviews with students and chefs. The aim of the analysis is to understand how participants experienced the integration of design practices and digital fabrication technologies within the context of gastronomy education, and how these experiences shaped their creative, technical, and professional development. Guided by the study's design-based learning and digital prototyping framework, recurring patterns and shared meanings were identified in the data, allowing for a holistic interpretation of students' evolving competencies, the challenges they encountered, and the value they attributed to these learning processes. Insights from chef interviews further reinforced and deepened the patterns emerging from student data, contributing to a multi-perspective understanding within the analysis. The findings are presented across four core themes, each reflecting a distinct dimension of how design and technology influenced students' approaches to culinary creation and future career trajectories.

4.1.1 Theme 1: Creativity and Innovation in Culinary Design

This theme examines how students and chefs integrated creative thinking and design-based approaches into culinary practices. The findings reveal that participants approached the cooking process not merely as a technical activity but as a design practice situated at the intersection of aesthetics, innovation, and technology. Throughout this process, students were observed to apply the principles of design thinking, particularly in their problem-solving and creative decision-making stages. Survey and interview data indicate that students actively used digital fabrication tools such as laser cutters, 3D printers, vacuum forming, and silicone molding to transform their ideas into tangible gastronomic forms. Engaging with these tools enabled students to redefine design as a form of expression within gastronomy, reflecting their individual creative identities through the process of making (Coşkun & Baykal, 2025).

4.1.1.1 Creative Presentation Through Innovative Plate Design

The pre-survey results indicate that students planned to integrate innovative approaches in gastronomy, particularly through plate design and presentation aesthetics, into their professional practices. Before the course began, the majority of students expressed a strong desire to design creative and distinctive plates. This motivation was combined with the goal of creating "visually strong, unique, and signature plates," generating a shared awareness that presentation is an integral part of the dining experience (Pre-survey, Q2, Q4). The survey responses also revealed that creative plating techniques not only enhance the visual appeal of dishes but also contribute to building brand value as part of the chef's professional identity.

By the end of the course, post-survey evaluations showed that students were able to successfully apply the molds and forms they had developed in their plate presentations. This demonstrated the tangible transformation of creative ideas into gastronomic outcomes, representing a complementary indicator of the learning process. Students described this experience as highly motivating:

"It was very satisfying to see the final product working on the plate." (S3,S1)

This statement illustrates how innovative plate design fosters a sense of achievement and motivation in the learning process. During the practical sessions, techniques such as silicone molding, vacuum forming, and 3D design were recognized as methods that enhanced presentation aesthetics and provided practical learning outcomes. Students emphasized that these technical experiences built a strong foundation for developing their own signature plates in their future professional work (Post-survey).

Post-survey data also revealed that students perceived digital fabrication tools as a natural component of their creative processes. Approximately 80% of participants reported using at least one digital fabrication tool, most frequently laser cutting and 3D printing, to support their creative plate design experiments (Table 4.1). These tools allowed students to go beyond the boundaries of traditional plating by designing and producing their own templates, molds, and cutters. Students highlighted Openfab as an inspiring learning environment that encouraged experimentation, idea sharing, and collaboration through digital tools. One student summarized this experience as follows:

Table 4.1 *Summary of the Digital Tools Used, Number of Participating Students, and the Total Prototypes Produced Across the Study*

Digital Tools	**Number of Students**	**Prototypes**
Laser cutter	25	27
3D printing	20	82
Vacuum molding	22	27
Silicone molding	9	14
3D scanner	2	1

"It was great to create my own designs and recipes. I felt more professional." (S15)

Interview data further demonstrated that students perceived the design process as a creative practice that directly enhanced both the aesthetic and functional qualities of plate presentation. Participants stated that they prioritized the harmony between food and presentation during the idea development phase. As one participant described from their professional experience, this approach was also influenced by real-world kitchen practices:

"In the restaurant where I worked in Barcelona, they were using a similar mold for desserts, but I wanted to adapt it for a cutter." (S10)

Similarly, another student reflected on her creative process, noting:

"Sometimes I look at inspiration sources like Instagram or Pinterest, take ideas from different things, and then create my own design." (S24)

These reflections indicate that through digital fabrication, students not only developed technical skills but also cultivated their personal aesthetic sensibilities. The creative presentation process thus contributed directly to the development of professional authenticity and self-expression.

Chef interviews further supported these findings. Chefs noted that students' ability to relate aesthetic decision-making to material experimentation enhanced their design sensitivity in plate presentations. These practices transformed the plate from a mere serving surface into a designed medium carrying narrative, texture, and identity. One chef (C1) emphasized the importance of personalization, stating, *"The main thing is to personalize every dish,"* and highlighted the emotional and experiential dimension of design: *"The mold can give an added value to the story the chef wants to express."* (C1) Moreover, the same chef also noted, *"Design programs will be supported by AI,"* suggesting that AI-assisted design approaches may accelerate creative innovation in gastronomy in the future. Another chef (C3) mentioned the potential use of printing and chocolate logos on plates as a means of branding within culinary design.

Overall, these findings indicate that innovative plate design in gastronomy carries not only aesthetic value but also functions as a strategic communication tool that integrates narrative, identity, and experiential design.

4.1.1.2 Designing and Creating With Technologies in Culinary Design

Beyond visual creativity, the use of technological tools expanded students' capacity to prototype and materialize their ideas. Survey data (Q4, Q9) indicated that nearly all students gained hands-on experience in 3D printing or mold-making techniques during the course, and the majority planned to continue using these tools in their future careers. These findings demonstrate the emergence of a technology-driven form of creative thinking within culinary education.

Students emphasized that working with digital fabrication tools was not merely a technical improvement but a process that encouraged them to reconsider the aesthetics of food. As one participant explained:

"As we did in class, all the designs can be applied to plates. Having this knowledge will enhance my creativity in the future." (S4)

Interview findings showed that students perceived technology in culinary design not as a supporting tool but as a core production component that translates creative thought into tangible outcomes. Digital modeling software (e.g., Fusion 360), 3D scanning, 3D printing, silicone molding, and vacuum forming techniques expanded students' capacity to transform ideas into real prototypes. For instance, one participant described the collaborative use of multiple tools:

"The model was printed with flexible filament, and the silicone mold was produced simultaneously."(S15)

Another participant highlighted the role of experimentation, stating:

"I tried all production methods and developed ideas based on them." (S10)

Similarly, another student described the seamless transition from digital to physical production:

"We put it in the 3D scanner and scanned it… then produced the mold in vacuum forming." (S7)

These findings reveal that students adopted technology-based design methods that combined experimentation, iteration, and creativity, developing a design-oriented and innovation-driven learning culture in gastronomy. Students also expressed their willingness to continue applying these approaches in their professional practice, indicating that technology is becoming an integral part of their future creative processes.

Chef interviews supported this observation. Chefs emphasized that technology plays a decisive role in transforming creative ideas into tangible outcomes, highlighting how digital tools enhance both efficiency and creative potential in culinary design. One chef explained that *"the cutter goes much faster than cutting with a knife,"* illustrating how technological tools improve speed and consistency in production (C3). Another pointed out the limitations of industrial equipment, noting that *"you cannot find them… cannot buy them,"* emphasizing the necessity of custom-designed molds in professional kitchens (C2). A different chef referred to the use of design programs such as Fusion 360 and 3D printing as providing *"creative freedom,"* underlining the flexibility these tools offer for individualized creation (C1). The same chef also predicted that *"design programs will be supported by AI,"* suggesting that artificial intelligence will further expand creative boundaries and accelerate the pace of innovation in gastronomy (C1). Collectively, these insights demonstrate that professional chefs perceive technology not as a replacement for craftsmanship but as an enabler that bridges imagination and material execution in culinary production.

Overall, these insights illustrate that technology in culinary education is no longer a mere facilitator but a creative catalyst, enabling students and professionals to prototype, innovate, and express culinary ideas through a design-based, technology-integrated approach.

Building on the insights gained from creativity and technological production processes, the following theme focuses on the challenges encountered during these design-oriented learning experiences and how students and chefs addressed them throughout the process.

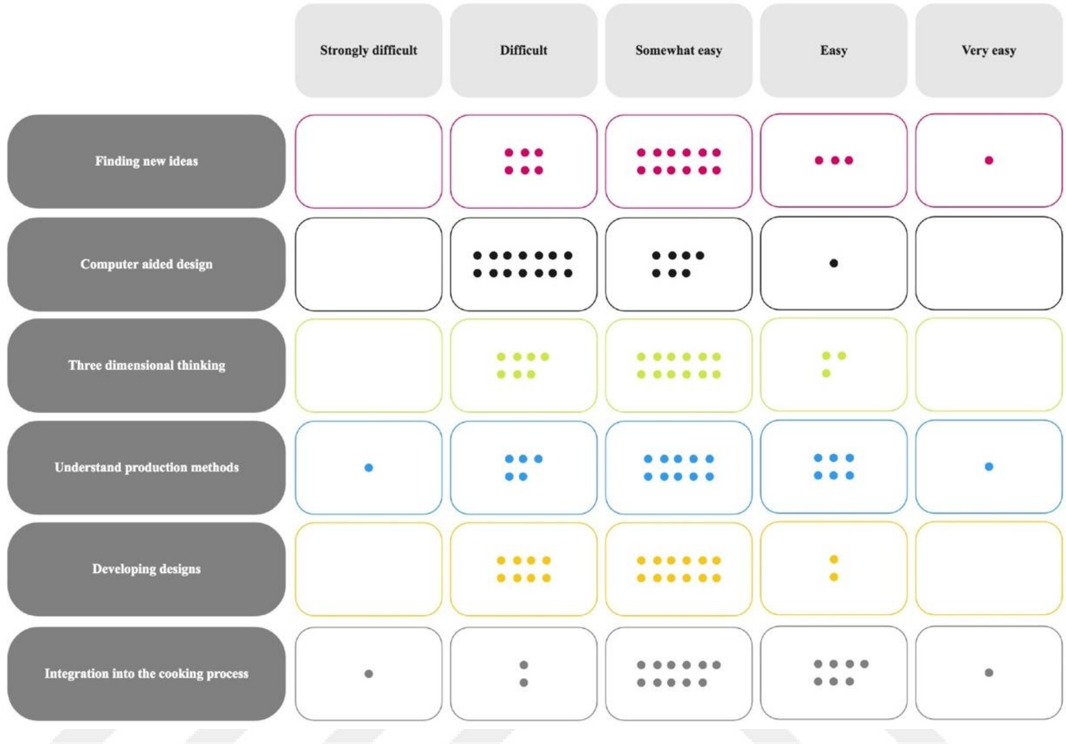
4.1.2 Theme 2: Challenges About the Process

This theme examines the challenges that students encountered while learning digital fabrication tools and design-based processes, as well as how these challenges contributed to their overall learning experience. None of the students had previously engaged in design or production using technological tools before the course, and only two students reported having limited prior experience with industrial mold production. Findings at the end of the course revealed that students faced various difficulties while implementing design-based approaches in gastronomy education, particularly in technological adaptation, computer-aided design (CAD) applications, and three-dimensional thinking. These challenges largely stemmed from the complexity of technological equipment, the process of adapting to new software interfaces, and the underdeveloped nature of spatial visualization skills at the beginning of the course. However, while overcoming these obstacles, students developed essential learning skills such as problem-solving, collaboration, and self-reflection. As a result, the process contributed not only to their technical growth but also to their cognitive and emotional development, indicating a holistic form of learning. Similarly, chefs noted that technological adaptation in professional kitchens presented comparable challenges within real-world culinary settings.

4.1.2.1 Navigating Technological Challenges in Process

During the research process, students reported that they experienced the greatest difficulties when interacting with digital technologies, particularly in the stages of computer-aided drawing, design development, and three-dimensional thinking. In contrast, most students stated that they did not struggle much with idea generation, understanding new production methods, or integrating the design into the cooking process. According to post-survey results (Q2), out of 22 students, 14 reported difficulties in computer-aided design, 8 in design development, and 7 in 3D thinking. Only one student indicated that integrating the design into the cooking process was “very difficult,” while two others marked it as “difficult.” These findings indicate that the integration of design into the cooking process was the area where students experienced the least challenge (Figure 4.1).

Figure 4.1 *Students' Reported Difficulty Levels in Digital and Design-Related Tasks Based on Post-survey (Q2) Results*



Individual interviews further supported the post-survey findings, confirming that designing with Fusion 360 software was one of the most challenging aspects of the process for students. Additionally, the most difficult areas were identified as selecting the appropriate production method and integrating the design into the dish. The interviews also revealed two challenges not addressed in the survey: transitioning from idea to design and issues related to measurement and scale. One participant expressed this difficulty as follows:

"It was difficult to translate my idea into a design and imagine its application in the kitchen." (S3)

Students stated that although they were unfamiliar with these tools at the beginning, they overcame the challenges through continuous feedback and experimentation. While they initially found computer-aided design complex, they later described it as a rewarding and enjoyable part of the learning experience:

"Seeing my drawing come to life and being able to use it in a dish… there was something in my mind, and then it became real." (S23)

"Creating a design, printing it, and waiting for the result with excitement was a very meaningful part of the process." (S14)

These reflections show that the process of overcoming technological barriers fostered the development of self-regulation, problem-solving, and persistence skills among students. One participant summarized this process as follows:

"Creating drawings on the computer was quite challenging at first, but as the process went on, I adapted and began to understand it more clearly." (S5)

Most students noted that they encountered various technical difficulties, particularly in learning the Fusion 360 interface, such as understanding complex commands, developing three-dimensional thinking, and identifying or correcting design errors.

"Every time I clicked on the interface, something different opened… adaptation was difficult for me." (S5)

"It was hard to get used to it at first; I didn't have the ability to perceive things in 3D." (S13)

"It was difficult to identify the parts in the program that could cause problems during production." (S15)

"While pouring the silicone, the model floated to the surface; we couldn't control it." (S2)

These statements demonstrate that digital production requires not only technical knowledge but also patience, continuity, and error management. Throughout the process, students became more aware of how to detect and correct their own mistakes, adding an experimental and reflective dimension to the design-based learning experience. Similar challenges were highlighted in the chef interviews, showing that professional kitchens also face comparable obstacles. One chef explained that material behavior often created design-related complexity, stating, *"Molding is the most difficult part… material and substance do not match."* (C2) Another chef discussed the quality differences between professional and student products, explaining, *"Printed products show layers… SLA is more expensive… food-safe constraints."* (C3) A third chef emphasized the importance of maintaining balance between design and flavor, noting, *"Flavor and texture must not be compromised for design."* (C1) These insights indicate that technological integration in gastronomy requires not only technical proficiency but also experimentation, testing, and material knowledge, making it a complex and multidimensional process.

4.1.2.2 Personal Growth Through Overcoming Challenges

The challenges encountered throughout the process contributed not only to technical learning but also to personal development. Students reported that they initially struggled with Fusion 360 and 3D design processes but gradually learned to use these technologies more effectively through repetition, experimentation, and collaboration. This experience enhanced their levels of self-confidence, patience, and self-awareness, transforming the learning process into an "experimental problem-solving journey" (Coşkun & Baykal, 2025).

Students stated that the difficulties they faced, particularly in silicone molding and vacuum forming, eventually turned into valuable learning experiences:

“While filling the silicone mold, the object floated to the surface and overflowed. At first, we struggled, but later we realized it wasn’t as difficult as we thought.” (S2)

“Small details played a much bigger role than I expected.” (S28)

These experiences indicate that students strengthened skills such as attention to detail, self-regulation, and awareness during the process. One participant summarized this transformation as follows:

“I enjoyed the whole challenging process because it was step by step, and every week brought a new improvement.” (S14)

Students described the process as both challenging and exciting. In addition to the skills they developed in culinary classes, they gained new forms of experience through prototype production and the use of technological tools.

“My training at Openfab was an incredibly enriching experience that deepened my understanding of culinary design and innovation.” (S23)

Such experiences enhanced not only their technical competencies but also their professional confidence and innovative thinking capacity. Students also emphasized that throughout the design development and iteration stages, they improved their problem-solving, critical thinking, and decision-making abilities.

By transferring their designs into the cooking process and producing molds and templates, students strengthened their professional competencies. Several participants stated that by the end of the course, they felt more professional and more aware of the industry’s expectations. Exploring new prototyping methods and actively engaging with technology increased their self-efficacy. Instead of stopping at challenging stages, students adopted a trial-and-error, reflective, and problem-solving learning approach.

This process not only fostered individual growth but also their teamwork and communication skills.

"Working toward a clear goal made me more efficient; it allowed me to explore my own ideas and materials." (P 13)

Most students expressed that the difficulties they faced guided their creativity and accelerated their professional development.

"Understanding modeling and the logic of production was challenging, but I eventually figured out how to create molds through 3D printing." (S15)

"The program was tiring, so I simplified my design approach." (S19)

These reflections show that students perceived the process not merely as a technical learning stage but as a personal growth experience that enhanced their self-efficacy, resilience, and creative direction. Post-survey data supported these findings: the majority of participants rated themselves as moderately to highly competent in creating new designs within the field of gastronomy. In responses to Question 9 of the survey, nine students rated themselves "3," eight rated "4," and five rated "5," indicating strong confidence in technology-based design. These results demonstrate that the technical difficulties experienced at the beginning were not barriers but rather learning opportunities that stimulated creativity and accelerated professional maturity (Table 4.2).

Similarly, the chef interviews revealed that these challenges played an instructive and developmental role. One chef emphasized the importance of experimentation, stating, "Trial and error is key… accidental discoveries lead to innovation," highlighting that mistakes are a natural and educational part of the process (C1). Another chef noted, "We should be ahead of the industry," indicating that such challenges foster innovation and forward-thinking in professional practice (C3). Collectively, these insights suggest that the difficulties encountered throughout the process contributed to the development of resilience, flexibility, and self-awareness among both students and professionals.

Table 4.2 *Students' Perceived Competency Levels in Applying New Technologies and Generating New Designs in Gastronomy After the Training*

Post-survey	**1**	**2**	**3**	**4**	**5**
Q9. After this training, how confident do you feel about creating new designs in the field of gastronomy?	0	1	10	7	5
Q9. After this training, how confident do you feel about creating new designs in the field of gastronomy?	0	0	9	9	5

Building upon the insights gained from how students and chefs navigated challenges during the learning process, the next theme explores how these experiences contributed to the development of new technical skills and professional competencies, highlighting the transformative role of technology in design-based culinary education.

4.1.3 Theme 3: Developing New Competencies

This theme focuses on how students in the field of gastronomy acquired new technical skills, developed self-confidence, and enhanced their technological awareness through the use of digital fabrication technologies. Throughout the learning process, students engaged with tools and methods they had never experienced before, strengthening both their technical competencies and their design-oriented thinking skills. The findings reveal that students perceived digital tools not merely as instruments of production, but as active components of problem-solving, creativity, and professional development within their learning process.

4.1.3.1 Acquiring New Technical Skills

The pre-survey results conducted in the first week of the course revealed that among the 27 participating students, none had previously designed or produced their own templates or molds. Only one student had experience with vacuum molding, and another with silicone molding. Through the course's integration of design and technology, students expressed their desire to "design and produce the necessary molds independently without relying on third parties," to "understand the working principles of 3D printers and apply them in their professional careers," and to "use self-designed molds and templates in unique plate designs" (Pre-survey). These findings indicate that while students initially had limited technological competence, they entered the course with a strong motivation and interest in design-oriented production.

Table 4.3 *Comparison of Prototype Development Activities and Experiential Gains at Different Stages of the Learning Process*

Post-Survey	Products	I had experience before the class.	I gained experience during the course.	I would like to use it in the future.
Q4.Please describe your experience with the following products.	Stencil	0	19	15
	3D-printed cutter	0	19	14
	3D-printed mold	0	17	16
	Vacuum mold	1	21	11
	Silicone mold	1	15	17

Throughout the research process, students developed their technical skills through the use of digital fabrication technologies. Post-survey results (Table 4.3) demonstrated a substantial difference between the tools students had experienced before the course, those they practiced during the course, and those they planned to use in the future. During the semester, students focused on vacuum forming, stencil production with laser cutting, and mold and cutter design using 3D printing. By the end of the course, a total of 151 prototypes had been produced, the highest number through 3D printing (82 prototypes) , and the lowest through 3D scanning (1 experience). The frequent use of 3D printing for both mold making and plating demonstrated that students had transformed this technology into a functional design tool. Although they initially struggled with drawing in Fusion 360, their ability to produce successful 3D print outputs demonstrated progress in problem-solving and adaptation skills. While only two students used a 3D scanner, all students actively engaged with at least three different digital fabrication tools and successfully presented the integration of their prototypes into dish presentations during the Second Design Presentation.

Interview findings revealed that students perceived this process not merely as a technical learning experience but as an opportunity where creativity became tangible. One participant described the process as follows:

"Transforming any idea I had into something tangible was incredibly enjoyable, and I loved being able to use my creative side." (S17)

Another participant emphasized the importance of material selection and three-dimensional thinking:

"I am able to transfer the design I imagine into my plate presentations. Thinking in 3D and making material decisions based on the mold are among the skills I learned in this process." (S14)

A third participant highlighted the practical benefits of learning new techniques:

"Using silicone molds and vacuum forming was really enjoyable, and I will definitely use these techniques in my future dessert designs." (S2)

These statements indicate clear improvement in students' computer-aided design and prototyping capabilities. Open-ended survey responses (Q5, Q10) supported these findings, with many students emphasizing that working with digital tools provided a hands-on experience that materialized creativity.

These findings align with the (Coşkun & Baykal, 2025) study, which stated that:

"Although students were inexperienced at the beginning, they became proficient in transforming their designs into prototypes using the correct methods by the end of the process."

Similarly, in this study, the technical knowledge and skills acquired throughout the course provided a strong foundation for students to integrate digital fabrication technologies more effectively into their future careers in gastronomy (Q7, Q8, Q9).

Chef interviews further demonstrated that design and production technologies provide a competitive advantage in gastronomy. One chef stated, "This is a skill which no other cooking school offers," emphasizing that technological proficiency differentiates graduates within the industry (C2). Another chef highlighted the transformative nature of technology in redefining professional kitchen roles, stating, "New roles like 'Printer Manager' could emerge" (C1). These insights reveal that digital fabrication skills are not only technical assets but also critical components of professional transformation and career innovation in the evolving culinary landscape.

4.1.3.2 Building Confidence and Self-Awareness

Alongside their progress in design practice and the use of digital fabrication tools, students developed not only technical proficiency but also a greater sense of self-confidence and personal awareness. This growth became evident both in their ability to overcome technological challenges and in their successful integration of molds into culinary presentations (QS6, Q9). Students who initially found Fusion 360 and 3D design tools difficult to use gradually learned to handle them more effectively and began to trust their capacity to produce innovative designs. According to the survey results (Q8, Q9), the majority of students felt highly competent in their design processes, although many also expressed the need for additional experience in applying emerging technologies within the field of gastronomy.

The interview data further illustrated the development of self-efficacy and professional awareness throughout this process.

"I believe I will be able to produce the molds I need in my own restaurant in the future." (S3)

"It was very satisfying to see the product I created actually work on the plate." (S24)

"I have gained some knowledge, even at a beginner level, in a field where very few people in the industry are knowledgeable." (S13)

These statements show that students not only strengthened their technical capabilities but also cultivated self-assessment, learning motivation, and professional confidence. Similarly, students "gained confidence by overcoming challenges and began to trust their own creativity" (Coşkun & Baykal, 2025). Successfully completing technology-based production processes contributed to students' sense of achievement and self-efficacy. One chef (C1) noted that "*students [were] positively impacted by achievements,*" emphasizing that such accomplishments played a vital role in developing professional confidence. This progression suggests that students were no longer positioned solely as practitioners but were beginning to evolve into chef-designers, professionals capable of integrating creativity, technology, and culinary artistry.

Building upon the development of technical skills, confidence, and self-awareness, the following theme examines how these newly acquired competencies are translated into students' professional aspirations and future career planning in the field of gastronomy.

4.1.4 Theme 4: Feeling Prepared for the Future

This theme explores how students plan to integrate the technical, creative, and technological skills they have acquired in the field of gastronomy into their future professional careers. The findings indicate that students believe the skills they gained through digital fabrication tools will have a lasting impact not only during the course but also in their professional practice. This theme reveals a transformation in which students translate their technological awareness into career vision, perceive innovative thinking as a professional advantage, and develop a strong sense of future-oriented confidence.

4.1.4.1 Preparing for Future Career Opportunities

Students stated that they planned to actively apply the design knowledge and technological skills they acquired during the course in their future careers (Q7). They also expressed a desire to use the products they learned to design and produce during the course in their professional practice (Q4, Table 4.3). Students reported that they intended to use silicone molds most frequently in the future, followed by 3D-printed molds and laser-cut stencils. According to the survey results, the majority of students indicated that they planned to apply their design knowledge and technological tools in their gastronomy careers (Q8, Q9). This finding aligns with the Coşkun and Baykal (2025, p. 9) study, which concluded that "students gained new perspectives in their professional development through the knowledge, experience, and awareness they acquired." Students emphasized that working with digital tools provided not only technical skills but also opportunities for entrepreneurship, creativity, and the development of an authentic brand identity. Several students shared their ambitions to open their own restaurants or to develop innovative presentations within existing establishments:

"This experience will definitely be useful for plating in high-end restaurants." (S4)

"In the restaurant I will work at or open, I plan to create the menu and plates using my own molds." (S14)

"I absolutely plan to integrate the design knowledge and technological tools I learned into my gastronomy career. My ultimate goal is to open a fine dining Palestinian restaurant with a unique identity, and what I learned in this course will play an important role in shaping it." (S23)

These statements demonstrate that students perceive the knowledge and skills gained through creative and technological practices not merely as an educational achievement but as a forward-looking professional strategy. Although the interview data did not directly address this theme, the survey findings clearly revealed students' strong tendency to integrate technology and design into their career planning.

Chef interviews reinforced this perspective, indicating that technological literacy is becoming a fundamental requirement for future employment in gastronomy. One chef (C2) stated, *"This knowledge will give them an advantage when entering the industry,"* emphasizing that technological competence would provide a competitive advantage for graduates entering the workforce. Another chef (C3) noted, *"New collaborations… great opportunity,"* highlighting that these skills open pathways for multidisciplinary collaboration. A further chef (C1) remarked that *"Technology will soon become common in large hotels,"* signaling that this transformation is expected to occur in the near future across the industry. These insights collectively suggest that the digital competencies acquired by students are not only tools for individual growth but also a strategic necessity for the next generation of gastronomy professionals.

4.1.4.2 Integration of Learned Competencies Into Career

Throughout the course, students demonstrated a strong motivation to integrate the technological and creative skills they acquired into their professional lives. Before the program, none of the students had any experience designing or producing their own molds or stencils; however, by the end of the semester, all participants expressed their intention to use personalized molds and templates in the future (Q7, Q4). Several students specifically stated that they wished to continue working with silicone molds and 3D printing technologies, while vacuum forming was mentioned as the least preferred method (Q4). These preferences indicate that students developed technological literacy and the ability to make conscious, purpose-oriented decisions regarding which tools best serve different design goals.

Interview findings revealed that students evaluated this process not only in terms of technical competence but also as an opportunity to strengthen leadership, time management, and teamwork skills:

"I believe I will be able to produce the molds I need in my own restaurant in the future." (S3)

"I especially plan to use cutters and molds extensively while designing desserts." (S2)

"I believe that integrating what I learned in this course into the field of gastronomy will make a significant contribution to my career." (S23)

These reflections illustrate that students perceived the skills they developed during the course not only as technical capabilities but also as a form of strategic professional advantage. Similarly, open-ended survey responses (Q10) revealed that students viewed the course as one that *"raised awareness about the future" and "encouraged the creative use of technology."* Together, these findings suggest that students positioned technology-based design learning at the core of their emerging professional identities.

Chef interviews further reinforced this observation. One chef (C3) stated that *"We should be ahead of the industry,"* emphasizing that the technological competencies gained through the course should become an integral part of professional identity, not merely a classroom skill. Another chef (C1) explained that as students experimented with various technological tools, they gradually learned which methods best suited their design purposes. According to this chef, working with molds, cutters, stencils, and vacuum forming encouraged students to make informed design choices through trial and reflection, helping them recognize which techniques were most effective for their intended goals. Taken together, these insights demonstrate that students combined their growing digital skills with strategic thinking, adaptability, and a deepening sense of professional awareness, marking a key step in their transformation into technologically literate culinary professionals.

4.2 Findings From the Content Analysis of Student Outcomes and Progresses

This content analysis was conducted exclusively using student-generated data and employed a mixed-method approach that integrated both quantitative and qualitative evidence. The analysis drew upon multiple sources, including prototypes produced throughout the course, the First and Second Design Presentations, student interviews, and jury evaluations. These materials were examined holistically to trace students' design processes, design development, iterations, problem-solving strategies, and their use of digital fabrication tools. The content analysis resulted in three main categories: (1) Design-Based Practices and the Evolution of Creative Processes, (2) Integration of Digital Fabrication into Culinary Practices, and (3) Integrated Learning Outcomes Supported by Jury Performance.

4.2.1 Design-Based Practices & Evolution of Creative Processes

4.2.1.1 Ideation, Sketching & Intent Formation

In this study, students approached gastronomic production not merely as a culinary practice but as a multidimensional design problem that can be systematically addressed through creative processes. Accordingly, ideation, research, sketching, and the formation of plating-oriented design intent progressed simultaneously. To support this early-stage ideation phase, a shared digital folder titled *"Inspiration"* accessible to all students, was created on Drive, enabling them to compile reference imagery, moodboards, and research materials collaboratively.

The analysis revealed that sources of inspiration varied considerably among students, demonstrating diverse motivational pathways. Four main tendencies were identified:

(i) those who drew from professional kitchen experiences in shaping their design ideas (S1),

(ii) those seeking strategic differentiation by shifting away from common dessert-focused directions (S13),

(iii) those who developed ideas based on plate compositions observed on social media, particularly Pinterest and Instagram (S3, S7, S16, S24), and

(iv) those who directly translated online visual references into digital models (S7, S10).

This diversity indicates that students' design motivations were shaped not only by aesthetic intentions but also by contextual and cultural references grounded in their own lived experiences. Three distinct strategies were observed in how students initiated their design processes:

• sketch-based approaches relying on hand drawing,

• digital sketch–driven ideation, and

• workflows beginning directly with CAD modeling.

Some students explored geometric forms through iterative digital experimentation (S3, S15), while others integrated hand drawings into Fusion360 by scaling them into accurate digital models (S5). The Fusion360 instructional videos provided in the course supported technical proficiency in sketch-import workflows, reference scaling, and fundamental geometric operations, contributing to progressively more informed design decision-making.

To ensure the design intent was clearly articulated in the early phases, students presented their concepts during the First and Second Design Presentations, where they explained how prototypes would integrate with specific recipes, their spatial placement on the plate, and their rationale for visual coherence. Consequently, the design process evolved into a comprehensive decision-making practice that embeds functionality, service convenience, user experience, and dish composition, rather than focusing solely on aesthetic enhancements (Figure 4.2).

Figure 4.2 *Examples of Students' Conceptual Development During the Ideation Process*

Overall, these findings demonstrate that students perceived gastronomic product design as an integrated form–function challenge. Digital fabrication technologies were not adopted as incidental tools; instead, they functioned as supportive decision-making instruments that carry design intent and transform gastronomic outcomes.

4.2.1.2 Iterative Cycles & Problem-Solving Strategies

In this study, students' digital fabrication processes did not follow a linear design flow; instead, they evolved iteratively, driven by technical requirements, gastronomic functionality, and experimental trial-and-error. By the end of the semester, 24 out of 29 students (83%) had made at least one revision to their designs, prototypes, or recipes, while only 5 students continued with their initial implementations without modification.

This indicates that the learning process was predominantly shaped by continuous refinement and feedback-driven improvement.

Iterative revisions were primarily associated with:

- limitations of digital fabrication (e.g., negative spaces, inadequate wall thickness, scaling distortions),

- functional issues identified during plating (e.g., orientation and usability of forms), and

- interactions with edible materials (e.g., deformation during demolding, freezing-baking behavior).

Field observations revealed that students improved their problem-solving strategies over time: adding bridges to prevent stencil breakage, reversing positive–negative forms to achieve the intended plating imprint, and correcting scaled drawings that became distorted after importing into the software. Similarly, 3D-printed models with overly fine or dense details required manufacturability-oriented adjustments.

These findings are strongly supported by student reflections collected during the SDP presentations (Table 4.4).

Table 4.4 *Students' Prototype Revision Actions, Their Reasons, and the Associated Awareness Dimensions*

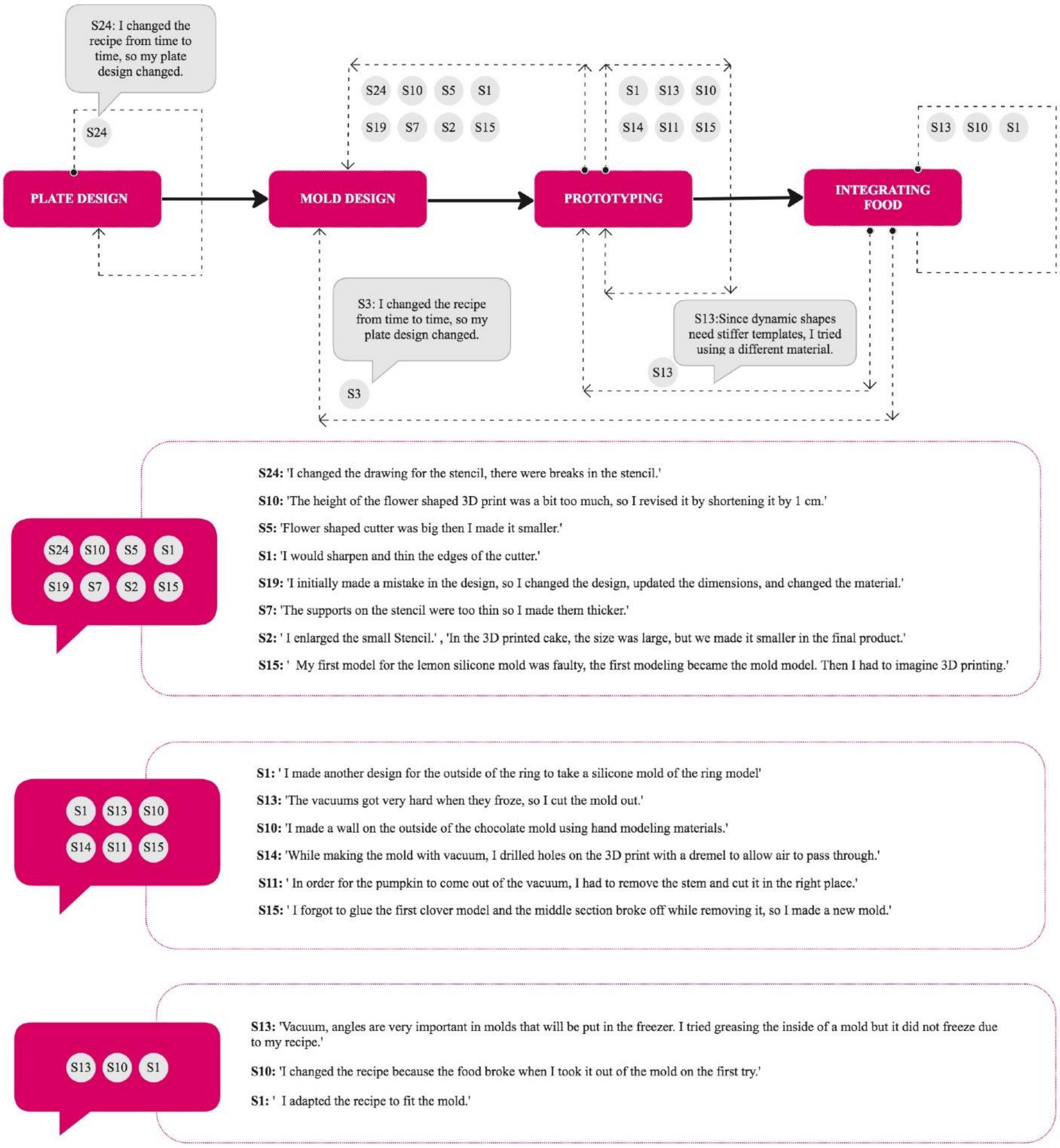
Participants	Iteration Experience	Reason for Iteration
S15	Realized an initial modeling mistake after printing and updated the design accordingly.	Direction of form / functional awareness
S10	Revised the design due to excessively thin wall thickness.	Failure to perform its function
S11	Changed the visual form after failing to achieve the desired outcome.	Visual / form refinement

Participants	Iteration Experience	Reason for Iteration
S19	Updated the measurements and changed the material to improve performance.	Material compatibility
S2	Adjusted the stencil size after observing mismatch during plating.	Food tool fit / usability

Iteration emerged not only in digital designs, but also in recipe development practices. Issues such as demolding difficulties, structural inconsistencies, and changes in texture during freezing or baking led students to adapt recipes to meet form-related constraints. For instance, a student redesigned the outer geometry of a ring mold to ensure proper performance during plating, while another explored different silicone shore hardness values to optimize the demolding behavior. This demonstrates that recipe adaptation became an integral and coevolving component of the production process.

Although most students initially planned to rely solely on 3D printing, final outcomes revealed that all students produced at least one laser-cut stencil, one casting mold (vacuum or silicone), and one 3D-printed tool by the end of the semester (Table 4.1). Thus, students shifted from depending on a single technology to employing multi-tool integration strategies informed by material behavior, fabrication challenges, and gastronomic application.

Figure 4.3 *Mapping the Iterative Transitions Across Design and Prototyping Stages*



Note. This figure synthesizes student reflections and observational data related to plate design, mold design, prototyping, and food integration stages.

Thus, iteration became not merely a method for correcting errors, but the primary driver of learning throughout the process. Figure 4.3 illustrates the multidirectional transitions students made between plate design, mold design, prototyping, and food integration stages throughout the semester. Built from SDP interview statements and researcher observations, this process mapping visualizes how students continuously navigated back and forth between design phases as new constraints and opportunities emerged. These iterative returns highlight that the design process was far from linear; instead, decisions were reshaped by fabrication limitations, food behavior, and aesthetic expectations. In this context, digital fabrication tools did not merely serve as production instruments but acted as cognitive enablers, helping students refine their ideas, validate their assumptions, and evolve their gastronomic creations in a dynamic learning cycle.

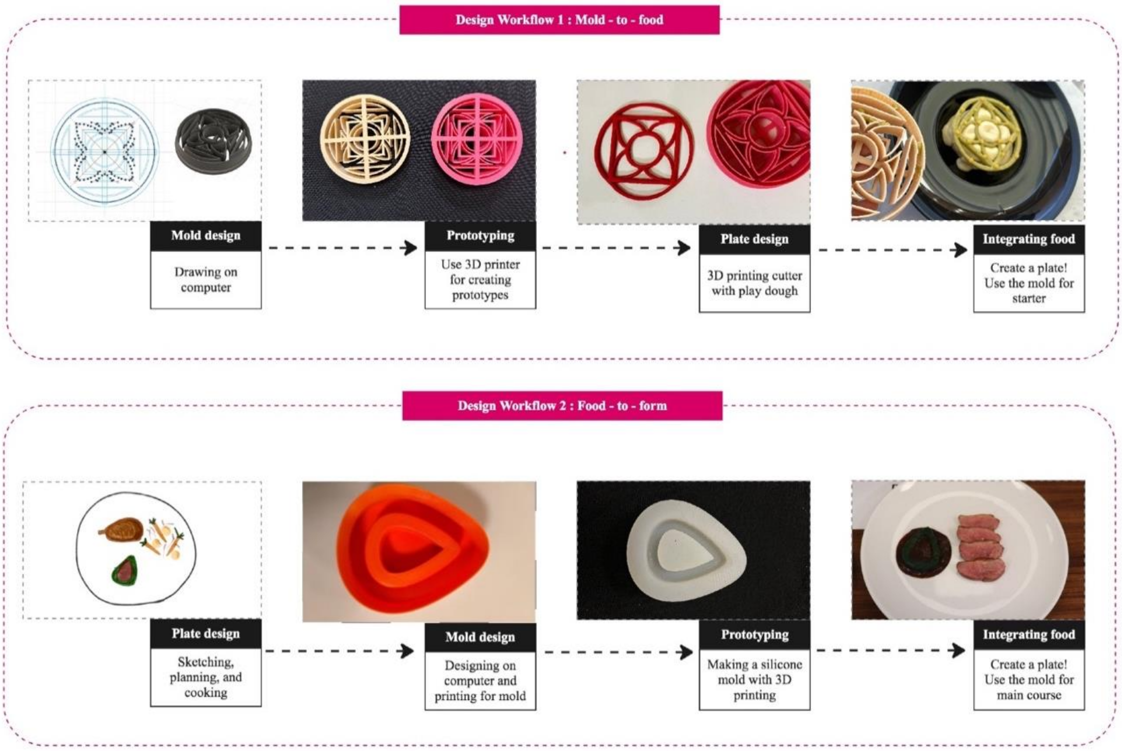
4.2.1.3 Design Flow Models in Gastronomy Integration

In this study, an examination of students' approaches to design revealed the absence of a single linear workflow; instead, an adaptable and evolving process emerged in which dish development and plate composition were addressed in different sequences. Of the 13 interviewed students, 9 began by defining the dish and subsequently developed the plate composition and prototypes. By contrast, 7 students started with the visual outcome they sought on the plate and shaped their mold or stencil designs accordingly. Additionally, 4 students experienced both approaches at different points during the term, indicating that the design workflow functioned less as a fixed method and more as a continuously reconfigured mode of thinking.

Based on these observations, two primary design workflows were categorized in the study. The first approach follows a mold-to-food sequence (Mold → Prototype → Plate → Food). In this model, students begin by digitally modeling the form they intend to transfer to the plate, then produce prototypes, construct plate compositions around that form, and finally adapt the dish to the design. The second approach proceeds in the opposite direction, a food-to-form sequence (Plate → Mold → Prototype → Food). Here, students initially define the gastronomic effect they aim to create on the plate, design the required mold or stencil accordingly, and then proceed to prototyping and fabrication. Although these workflows differ in their starting points, both ultimately culminate in the integration of food and form on the plate, illustrating that differing design logics can nonetheless converge toward a shared learning goal (see Figure 4.4).

Student reflections reinforced the representational strength of these two workflows. Those adopting a mold-to-food strategy frequently stated that they developed the form first and subsequently adapted the recipe to fit its constraints, whereas those following the food-to-form approach described shaping their design decisions in response to the desired final plating effect. These findings demonstrate that the design workflow functions not as a prescriptive pathway, but rather as a situational and adaptive problem-solving strategy, continuously reshaped by material behavior, food properties, and aesthetic intentions.

Figure 4.4 *Diagram of the Mold-to-food and Food-to-form Design Workflows Categorized in the Study*



These design workflows did not progress linearly; rather, each stage required students to make decisions in response to ongoing results. Several students revised their workflows as technical and gastronomic requirements evolved. Technical constraints, such as scaling errors, material incompatibility, volume miscalculations, and plating challenges, played an important role in reshaping the process. Examples include students who changed the intended course category after prototyping (S2), those who recognized insufficient wall thickness or lack of functionality and updated their models accordingly (S10), and those who redefined their dish selection based on the physical behavior of the prototype (S7, S19).

Thus, iteration became not merely a correction mechanism but the primary driver of learning, guiding students to navigate back and forth between decisions and outcomes across the design workflow.

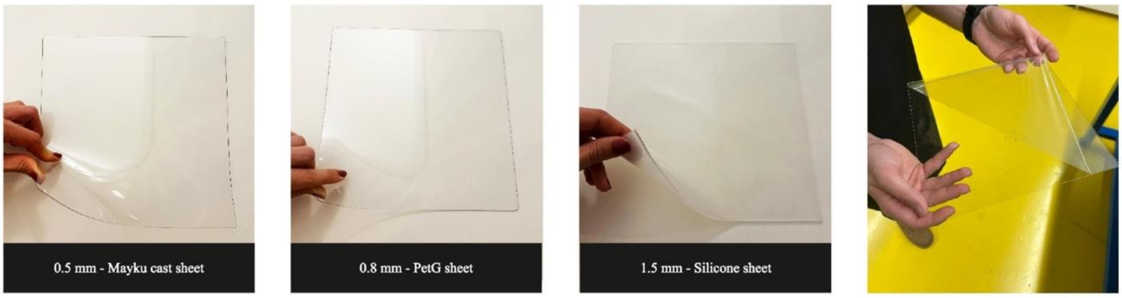
Ultimately, students developed unique trajectories shaped by their creative priorities and the technical demands of culinary fabrication. The experience demonstrated that different starting points can lead to equally innovative and gastronomically feasible outcomes, reinforcing the necessity of flexibility, interdisciplinary awareness, and integrated reasoning across visual, functional, and edible components.

4.2.2 Integration of Digital Fabrication Into Culinary Practices

4.2.2.1 Laser Cutting-Based Prototyping & Plating Applications

Students produced their stencil designs using the Epilog Helix 24 laser cutter located in Openfab. Laser cutting enabled rapid translation of digital drawings into physical prototypes, allowing the same form to be tested across multiple materials such as 80 g paper, PETG, Mayku sheet, and food-safe silicone. This capability supported quick iteration cycles and facilitated comparative observations of how material behavior affected plating performance. Compared to other fabrication methods used in the course, laser cutting proved to be faster, less labor-intensive, and highly suitable for early-stage prototyping.

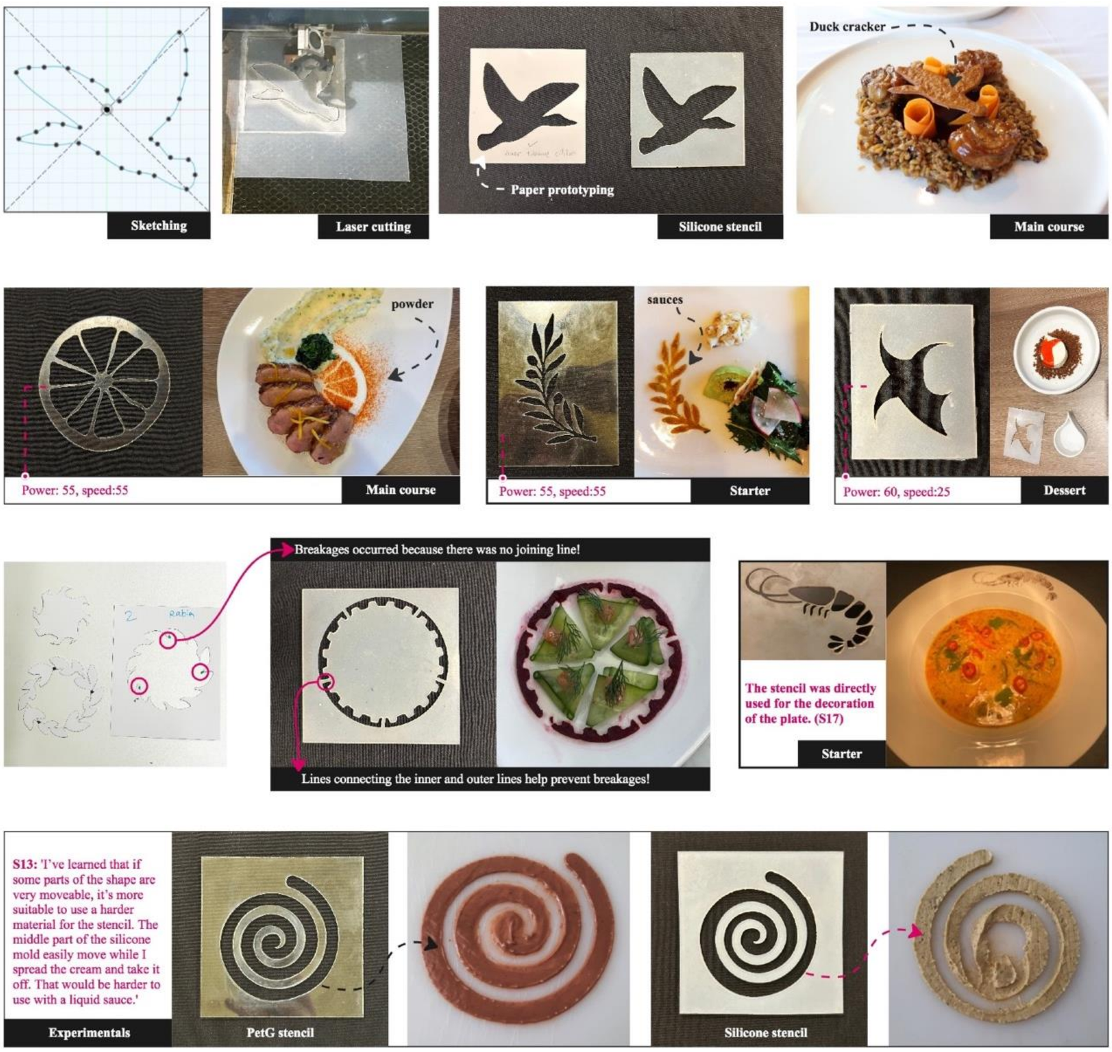
Figure 4.5 *Laser-Cut Materials and Their Properties for Stencil Making*



Before fabrication, students engaged in introductory Fusion 360 training focused on 2D drawing. Initial cuts were made on paper to evaluate scale–shape–function alignment, after which revised designs were exported in DXF format and produced using the selected materials (Figure 4.5). Students encountered challenges such as insufficient bridging of negative spaces, breakage-prone sharp corners, or scale distortions that became visible during food application. These issues were identified early in the paper prototyping stage and later resolved through digital revisions, reinforcing problem-solving skills and strengthening the link between design and fabrication logic.

Material behavior played a decisive role in product usability. Based on collective student feedback, Mayku sheet supported faster cutting but offered limited flexibility; PETG provided sharper contour definition suitable for sauce work; silicone required longer preparation and triple-pass cutting, yet remained the most preferred material due to its heat resistance and food safety. Students concluded that successful stencil performance depends not only on aesthetic qualities but also on material–recipe compatibility, ease of handling, and hygienic control during plating.

Figure 4.6 *Examples of Laser-Cut Prototypes, Illustrating Their Design and Production Processes and Plate Presentations*



Students submitted their DXF files to Openfab operators for production while maintaining the option to be present and observe the process. Across the term, 24 out of 28 students fabricated a total of 27 laser-cut stencil prototypes. The distribution of materials was: 12 silicone sheets, 9 PETG, 4 paper, and 2 Mayku sheets (Figure 4.6). During final jury presentations, stencils were actively used across amuse-bouche, starter, main course, and dessert plates. Templates were used in two of the plate presentations in the final jury, demonstrating that laser-cut components are widely integrated into kitchen workflows. For instance, duck crackers molded with silicone stencils were placed on a main course, while PETG and silicone stencils shaped sauces and purees. One student used the stencil purely as a decorative plate graphic, and another applied a jelly formed by a stencil directly onto a dessert plate by hand (researcher observation).

- **Scale and usage awareness**: Adjusting prototype size according to intended plate context (S7, S2)
- **Material–recipe co-adaptation**: Switching from tuiles to powdered garnish based on feasibility (S19)
- **Iterative revision**: Model updates following fabrication failures (S1)
- **Design-first strategy with recipe adaptation**: Developing the dish after the form is set (S3)
- **Re-contextualization & reinforcement**: Changing dish category or stencil thickness after testing (S2)
- **Backward planning from plating vision**: Determining the desired final look first (S24)

Overall, laser-cut stencil prototyping supported rapid fabrication, hands-on material comparison, and food-context alignment, forming a strong pedagogical bridge between design intent and gastronomic execution. The findings highlight that learning occurred through an iterative, material-responsive, and context-aware process, positioning digital fabrication as a meaningful component of interdisciplinary culinary design.

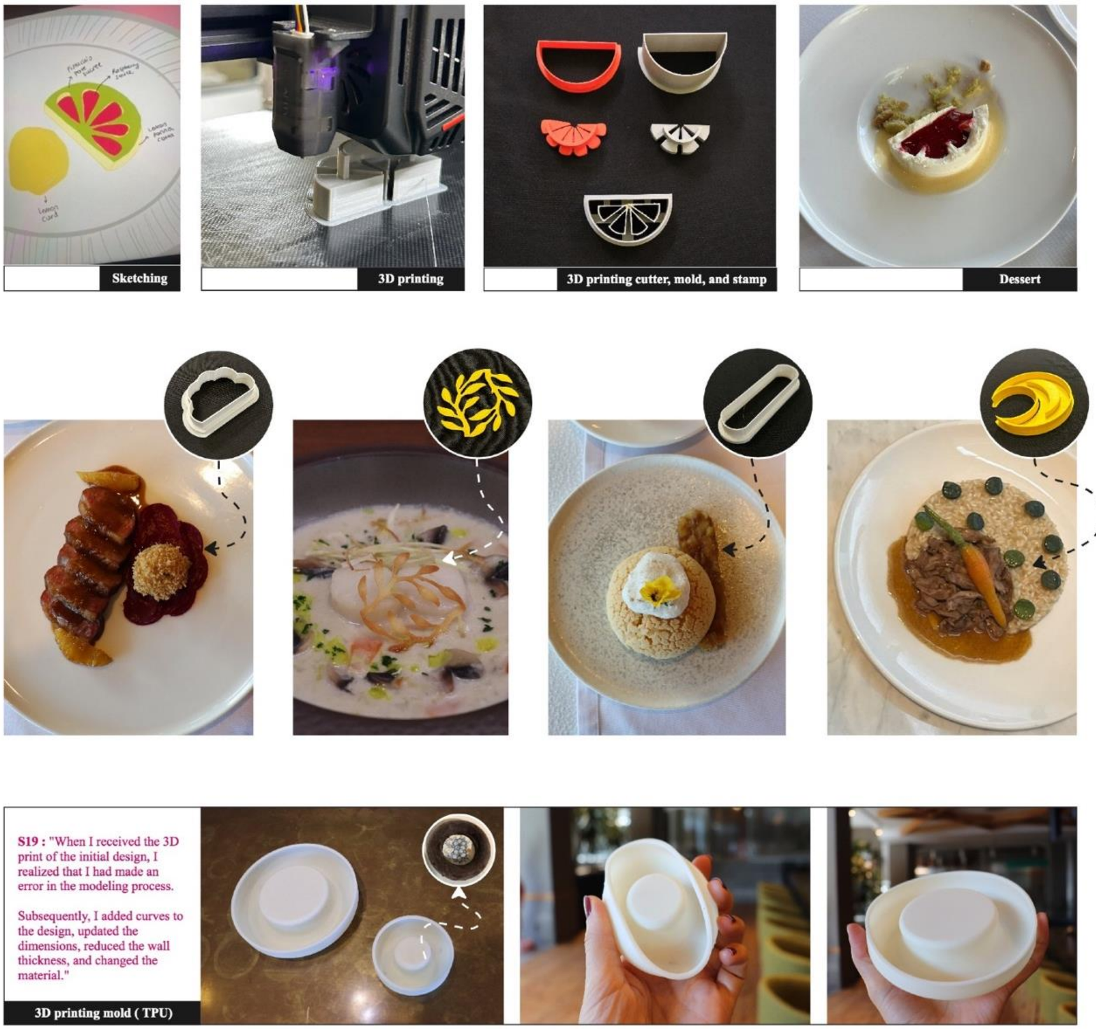
4.2.2.2 3D Printing for Modeling, Molding & Culinary Presentation

In this phase, students integrated digital modeling and physical prototyping into culinary applications through the use of FDM (Fused Deposition Modeling) 3D printers. Throughout the semester, they were introduced to the fundamental principles and dimensional constraints of FDM, including the requirement that no model surface thickness fall below the standard extrusion width of 0.4 mm. PLA and TPU filaments were predominantly used, and several students produced identical models in different materials to explore performance variations in food settings.

Students developed their models in Fusion 360 with the support of instructional videos provided via a shared Drive folder. The resulting STL files were reviewed for manufacturability, dimensional accuracy, and structural integrity before and after printing. Importantly, 3D-printed components served as versatile culinary tools, functioning as cutters, shaping molds, or direct food-contact molds depending on the gastronomic need.

In several instances, 3D printing directly enabled the creation of edible forms. For example, one student fabricated a dessert mold entirely from PLA filament and used a 3D-printed stamp to create sauce cavities on the dessert surface (Figure 4.7). Additional examples reflect the diversity of culinary implementation: a cloud-shaped cutter was used to form beetroot slices for a main course; another print generated the tuile pattern for a starter soup presentation; and a two-piece model was used to shape rice in a main dish. In another case, a student leveraged TPU’s flexibility by pouring pudding directly into the printed mold, freezing it, and placing the released form onto the plate, eliminating the need for a separate molding process.

Figure 4.7 *Examples of 3D Printing Prototypes, Illustrating Production Processes, and Resulting Plate Presentations*



Beyond direct plating applications, 3D-printed prototypes frequently acted as master models in vacuum forming and silicone molding workflows, demonstrating that students adopted additive manufacturing as a multifunctional tool across fabrication stages. Across the course, 20 students produced 82 unique 3D-printed models:

- 74 in PLA,

- 7 in TPU

- 5 students worked exclusively with TPU, 4 of whom eventually incorporated PLA as well.

Common technical challenges included dimensional inaccuracies, insufficient wall thickness, inadequate joining surfaces in multi-part models, and difficulty predicting mold behavior when casting food. These issues led to numerous iterations and revisions in both digital design and recipe formulation.

Findings from the Second Design Presentation revealed key learning outcomes related to multi-purpose tool development, material–recipe compatibility, plating standardization, and semantic–aesthetic integration. Students initially planned their prints for a single meal category, yet expanded usage scenarios across the menu, from starter, to main course, to dessert, as they recognized cross-functional opportunities:

"First, I planned to use my design for the main course, but then I turned to use it for the amuse-bouche."(S8)

Some discovered dual-functionality through practice:

"I used it for shaping tartare for starters and cutting cookies for my dessert." (S24)

Material constraints required adaptive decisions:

"I wanted to use this mold in my dessert, but since it wasn't suitable for the oven, I used it as a cutter instead." (S9)

Others extended their concepts with narrative intent:

"To have that connotation and add a dimension to the plate, I used it as a leaf shape." (S14)

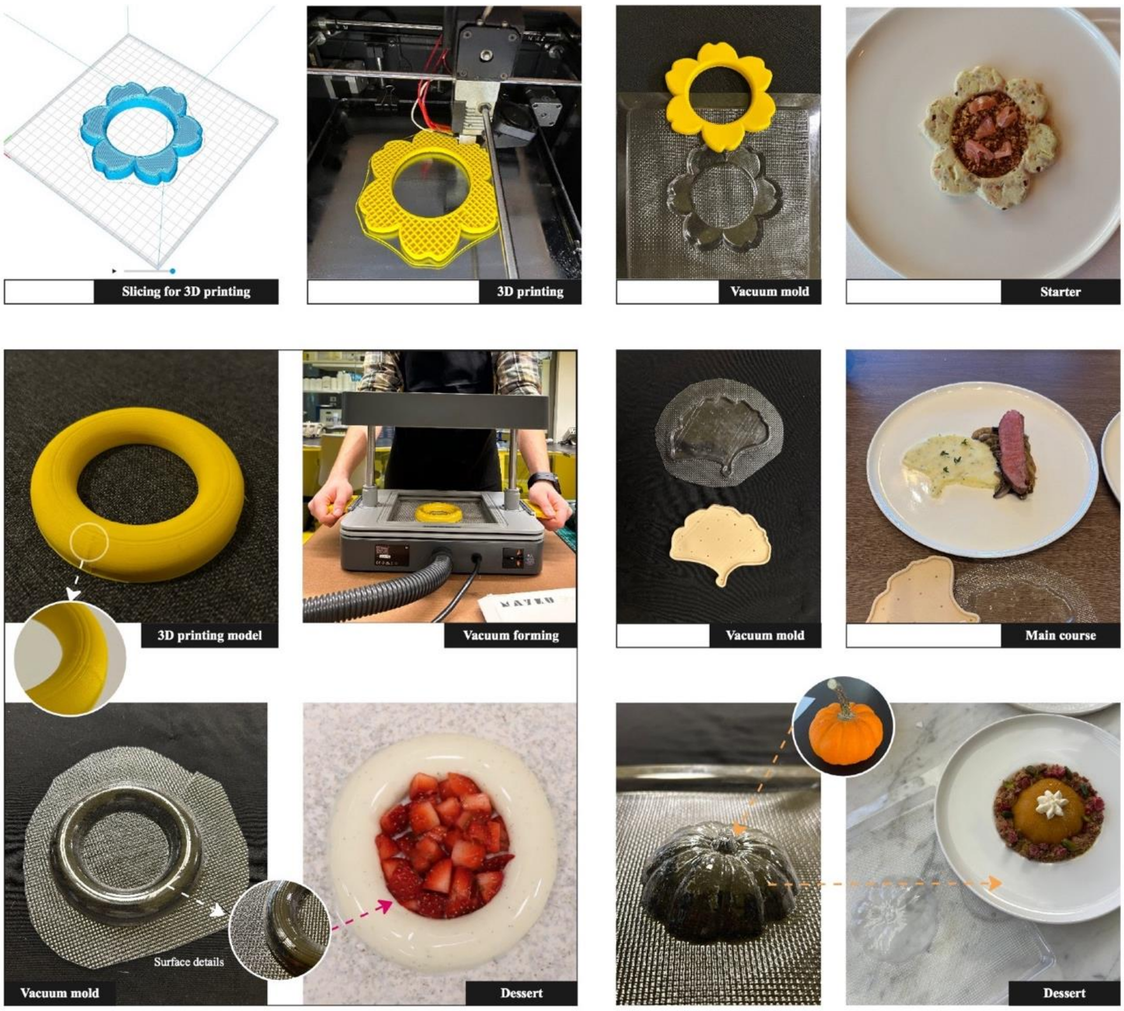
While only 7 of the 32 plates presented in the final jury included 3D-printed products directly, 19 plates incorporated them indirectly through silicone or vacuum molds derived from printed masters. This distinction highlights the extended design influence of 3D printing beyond the visible artifact.

4.2.2.3 Vacuum Forming-Based Food Mold Development

In this phase, students produced edible molds using the Mayku desktop vacuum-forming machine. In addition to learning the operational principles of the device, they were required to consider several factors during the design process, including the geometry, angles, and surface characteristics of the object to be molded, as well as its placement within the machine. A wide variety of objects were selected as mold models: 3D-printed forms, laser-cut pieces, natural items such as seashells, and hand-sculpted prototypes made from play dough. For instance, one student carved a real pumpkin to obtain a mold model, two students used seashells as shaping elements, and two others created original models using play dough. These variations indicate that students explored both digital and physical form generation methods.

Vacuum forming, commonly used in chocolate and pastry production, was integrated into starter, main course, and dessert presentations throughout the course (Figure 4.8). In one starter example, the mold was created from a 3D-printed model and refrigerated before plating. In a main course application, mashed potatoes were shaped using a vacuum-formed mold; air channels were added to the 3D-printed master model to improve mold quality, and recipe modifications were made to facilitate food release. In one dessert plate, the mold was directly obtained from a real pumpkin. In another case, the visible layer lines of the 3D print transferred onto the vacuum mold and consequently became apparent on the dessert surface.

Figure 4.8 *Examples of Vacuum Forming Prototypes, Illustrating Their Design, Production Processes, and Resulting Plate Presentations*



Across the semester, 22 students produced a total of 27 vacuum-formed molds. Due to shorter preparation and production times, vacuum forming was generally preferred over silicone molding during individual prototyping. However, during the final jury presentations, only 4 of the 32 plated dishes incorporated vacuum-formed components, indicating that although vacuum forming supports rapid iteration, only certain molds reached a gastronomically viable final application.

From the early stages of design, students began to account for the constraints imposed by vacuum-forming geometry. Some added ventilation holes to 3D models to enhance form accuracy, while others cut or revised their molds and adapted recipes to improve demolding success. Thus, the process evolved into an adaptive and multidimensional learning experience supported by technical awareness and real-time problem solving.

Second Design Presentation findings demonstrate that students developed a strong awareness of texture–form compatibility. They observed that formulations capable of freezing and maintaining structural stability are better suited for vacuum-formed molds. Accordingly, milk-based jellies, fruit gels, and dense purées were commonly used, while working with hard or brittle foods revealed the need for more careful technical considerations. Moreover, because vacuum-formed plastic lacks the elasticity of silicone, students learned the importance of controlling draft angles and wall transitions in model design.

Another key observation was the inter-course adaptability of vacuum-formed molds:

"At first, I planned to use the vacuum mold for the starter and dessert, but later I decided to add it to the main dish." (S13)

Students also recognized the influence of thickening agents, food thickness, and geometric aperture on mold-release performance:

"To remove it easily from the mold, I needed more stabilizer or to cut the salmon into smaller pieces." (S10)

Collectively, these findings show that vacuum forming helped students develop material literacy, recipe adaptation skills, multi-purpose usage strategies, and context-dependent problem-solving abilities. As such, vacuum forming became a powerful learning tool, allowing students to approach design holistically across flavor, texture, form, and plating context.

4.2.2.4 Silicone Casting and Mold Applications

For the silicone molding process, food-safe and oven-compatible RTV2 Craft silicone was used. The material consists of two components (A and B), mixed in a 1:1 ratio, and requires approximately 24 hours of curing once poured. Students selected silicone with different shore hardness values (5, 10, and 20) depending on the required flexibility, surface detailing, and structural stability of the intended food applications. Before designing their own molds, students were introduced to pre-existing silicone samples to gain an understanding of the tactile behavior, reusability, and geometric fidelity of silicone molding.

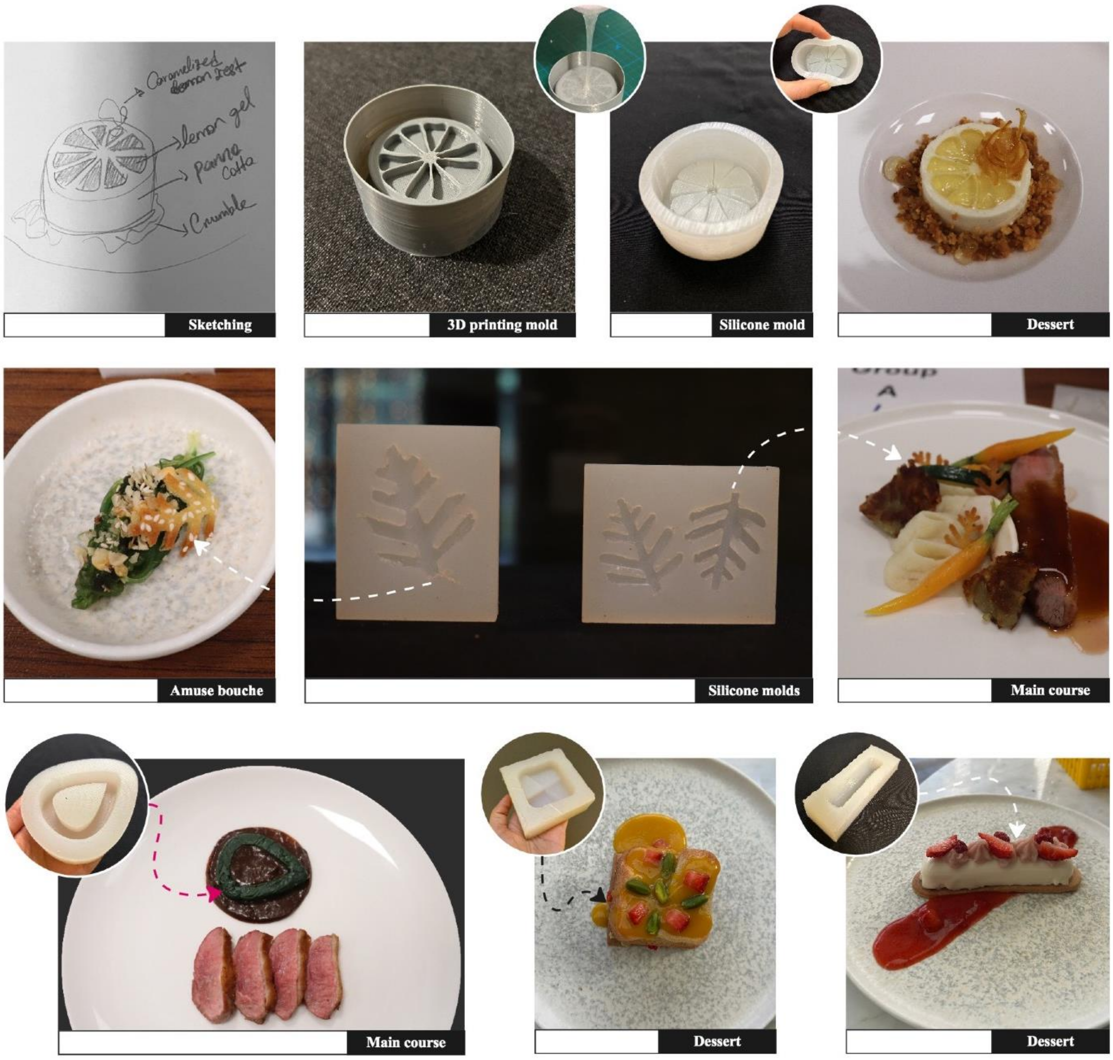
Students were encouraged to use their own 3D-printed models as the bases for silicone molds. Two approaches were used for constructing the mold cavity: (1) manually building a mold wall using model cardboard and adhesive, or (2) digitally designing it as a precise case in Fusion 360, ensuring consistent wall thickness.

The digital method enabled greater geometric accuracy and prevented silicone waste. A total of 14 silicone molds were produced by 9 students throughout the semester. These molds were incorporated into amuse-bouche, starter, main course, and dessert presentations (Fig. 4.9). For example, in a dessert application, a student produced both a 3D-printed master and a surrounding mold case, poured shore-5 silicone into the cavity, and later froze a cream-based mixture inside the cured mold. For amuse-bouche and main courses, students preferred shore-10 silicone, particularly when baking tuile preparations, as the medium hardness supported oven stability without compromising demolding. In another application, a thicker-walled mold was created using hand-built casing and used to shape boiled vegetables for plate arrangement. Students observed that wall thickness affected heat transfer and demolding time, influencing workflow in both freezing and baking scenarios. Across four menus presented in the final jury, 8 silicone molds were used on 32 plates, demonstrating the technique's strong integration into final outcomes.

Findings from the Second Design Presentations indicate that students gained experience with alternative molding techniques, such as TPU printing and vacuum forming, prior to applying silicone casting, enabling them to critically compare how material selection influences the performance and usability of the final product. Students designed outer mold casings in Fusion 360 and produced them with wall thicknesses of either 0.8 mm or 1.2 mm, maintaining a controlled spacing of 4–10 mm between the master model and the mold walls. This approach ensured both efficient silicone usage and adherence to sustainability principles (Figure 4.9).

Students also faced challenges in correctly conceptualizing positive–negative geometry relationships during the design phase. One student initially modeled the positive volume instead of the negative cavity required for molding and later revised the design after recognizing the error during casting. In addition, close internal geometries reduced flexibility during demolding, which caused surface distortions on the food product. To resolve this, the student reinforced the final presentation with a layer of gelatin, demonstrating real-time adaptation and reflective practice.

Figure 4.9 *Examples of Silicone Mold Prototypes, Sketches, Production Processes, and Resulting Plate Presentations*



Silicone's high level of detail capture also prompted several students to iteratively simplify model features or modify recipes to ensure successful demolding. As one student (S24) stated *"I reduced and changed the details of the 3D model to make it easier to remove from the mold."* Through continuous trial-and-error, students strengthened their understanding of material behavior, form–texture relationships, and process-driven decision-making.

4.2.2.5 3D Scanning for Adaptation in Food Design

Students were introduced to the MakerBot Digitizer 3D scanner and the accompanying software to convert scanned objects into digital models. Throughout the semester, they experimented with scanning objects of different scales, textures, and surface complexities. However, only two students incorporated the technology into their design workflows. One student scanned a seashell brought from Barcelona, duplicated the 3D model, and 3D-printed multiple copies, which were subsequently used to create vacuum-formed molds for food shaping (Figure 4.10). As the student explained:

"Since I really liked this seashell, I wanted to use it in my project. I scanned it, printed copies, and used them to create molds. The mold worked successfully." (S7)

Figure 4.10 *Creation of a Vacuum Mold From a Seashell Scanned With a 3D Scanner*

Another student attempted to scan and scale a pumpkin but discontinued the approach due to difficulties in modifying the complex digital geometry.

Although 3D scanning enabled material replication and the bridging of physical–digital workflows, several contextual factors appear to have limited its adoption. Researcher observations suggest that students gravitated toward techniques in which they could more directly construct and manipulate form, such as 3D modeling or laser cutting. The conceptual integration of scanning into culinary design was less intuitive for many, and the technical demands of editing scanned meshes increased cognitive and operational complexity. As a result, students preferred design tools that provided more immediate creative control and clearer pathways to gastronomic application.

While the seashell-based mold was successfully used in kitchen practice during studio sessions, it was not among the plates selected for final jury presentation. This outcome indicates that, despite its potential, 3D scanning remained primarily an exploratory and supplementary method rather than a dominant fabrication approach within final plate designs. Nevertheless, the experience provided valuable insights into adaptation, reverse engineering, and the translation of naturally occurring forms into culinary context.

4.2.3 Integrated Learning Outcomes Supported by Jury Performance

4.2.3.1 Transformation of Design Learning Outcomes Into Culinary Applications

The findings of this study demonstrate that the design-oriented learning outcomes students developed throughout the semester were successfully translated into the dishes presented during the final jury evaluation. Technical competencies related to the use of digital fabrication tools extended beyond prototype production and directly influenced core components of gastronomic design, including recipe development, plating decisions, food–material compatibility, and user experience.

While students initially positioned digital fabrication as an aesthetic enhancement or decorative add-on, by the end of the semester they had incorporated these technologies as structural, functional, and experiential elements of the dish. Qualitative data indicate a notable transformation in students' understanding of food–form coupling, recipe adaptation, plating standardization, and semantic/expressive functions that convey narrative and identity through food.

This transformation became particularly visible in the final menus through the following outcomes:

1. Digital fabrication components evolved from supplementary prototypes into core culinary elements that supported professional skill development (e.g., shaped potatoes, tuile formed in molds, molded panna cotta, chocolate shells).

2. Technical design decisions exerted direct influence on taste–texture–form compatibility, including recipe adjustments to ensure mold release and structural stability.

3. Prototypes expanded their role in the preparation process, functioning not only as shaping tools but also as baking vessels and identity-defining components of the dish.

4. Dishes exhibited measurable improvement in technical execution, creativity, and presentation quality as a result of integrated fabrication strategies.

Overall, this synthesis observed in the final jury presentations indicates that students no longer viewed digital manufacturing merely as a production method but rather adopted it as a conceptual driver of gastronomic innovation, actively shaping both the culinary process and the dining experience.

4.2.3.2 Frequency and Diversity in Students' Use of Digital Fabrication Tools in Final Menus

The final jury evaluation was conducted across two separate sessions, each featuring four student groups from different course sections. All groups presented their four-course tasting menus simultaneously (amuse-bouche, starter, main course, and dessert) allowing a direct comparative assessment of plating design and fabrication tool integration.

Across the 32 plates presented by eight groups, digital fabrication components were successfully integrated into 15 plates, corresponding to 21 prototype applications in total. This indicates that 48% of the final menu items included a digitally-fabricated stencil, cutter, mold, or food-shaping tool (Table 4.5).

These data indicate that digitally fabricated components were a meaningful part of the plating strategy in nearly half of the final dishes.

Table 4.5 *Digital Tools, Student Participation, Prototype Counts, and Final Jury Dish Outputs Across the Study*

Digital Tools	Number of Students	Prototypes	Final Jury
Laser cutter	25	27	2
3D printing	20	82	7
Vacuum molding	22	27	4
Silicone molding	9	14	8
3D scanner	2	1	0

When examined at the menu level, usage was concentrated primarily in dessert plates (8 instances), followed by main courses (3), starters (3), and only one amuse-bouche incorporating a digital tool. The highest integration occurred in Group 5, which utilized six prototypes across its amuse-bouche and dessert plates, including both silicone molds and 3D-printed components (Table 4.6). Furthermore, one menu demonstrated the most diverse integration, employing four distinct digital fabrication techniques across three courses: a vacuum-formed mold for the starter, a silicone stencil for the main course, and both a 3D-printed mold and a 3D-printed stamp for the dessert. To better understand the performance differences among design teams, Table 4.5 outlines how many prototypes each group implemented in their menu before examining their distribution by fabrication method.

Table 4.6 *Groups' Prototyping Methods and the Dishes They Presented in the Final Jury*

Group	Prototype Count	Courses Using Prototypes	Methods Used
G1	4	Starter, main course, dessert	Vacuum molding, laser cutting, 3D printing
G2	2	Main course, dessert	3D printing
G3	4	Starter, dessert	Vacuum molding, laser cutting, 3D printing
G4	1	Dessert	3D printing
G5	6	Amuse-bouche, dessert	Silicone molding, 3D printing
G6	1	Dessert	3D printing
G7	1	Dessert	Silicone molding
G8	3	Starter, main course, dessert	Silicone molding, vacuum molding

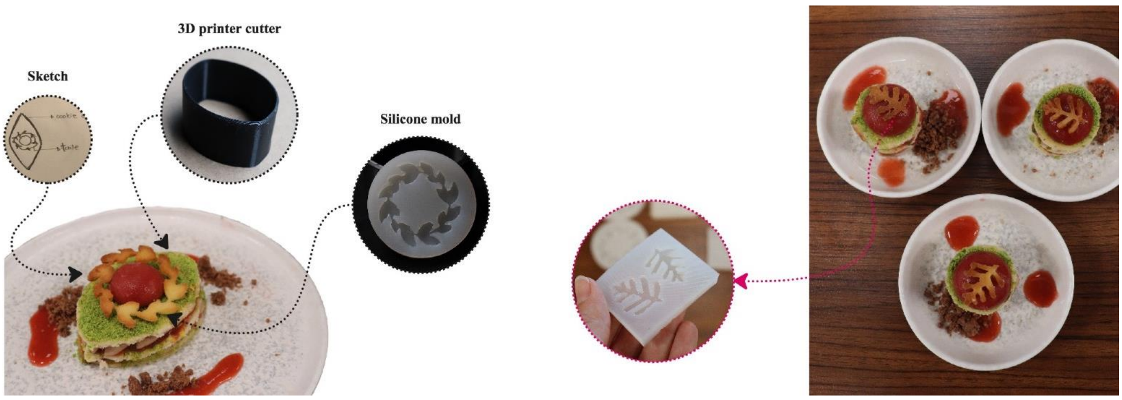
Although laser-cut stencils appeared sparingly in the final plates, observational evidence suggests a strategic shift: stencils did not directly contribute to the adaptation-grade rubric, leading students to prioritize three-dimensional and food-shaping tools that more strongly influenced evaluation outcomes.

These findings collectively indicate that digital fabrication has progressed beyond experimental usage and is now positioned as a functional and aesthetic design driver in culinary presentation. The frequency and diversity of application further suggest a broader pedagogical transformation: students increasingly view edible design elements not as decorative additions, but as integral components of flavor, texture, spatial composition, and narrative in gastronomy.

4.2.3.2 Cross-Method Integration in Single Plate

Analysis of the final jury revealed that multidisciplinary tool integration within a single plate occurred selectively but with strong conceptual awareness and technical control. Across eight menus and a total of 32 plated dishes, two dessert presentations incorporated multiple digital fabrication techniques simultaneously. In the first example, a 3D-printed cutter was used to shape the cookie base, while a silicone mold was employed to produce the baked tuile placed on top of the dessert (Figure 4.11). For the tasting versions presented to the jury, the student redesigned the silicone mold in a different scale, indicating an awareness of portion size, plate context, and operational adjustment for service conditions. By combining form manipulation and garnish production, the plate demonstrates how functionality and aesthetics were intentionally aligned.

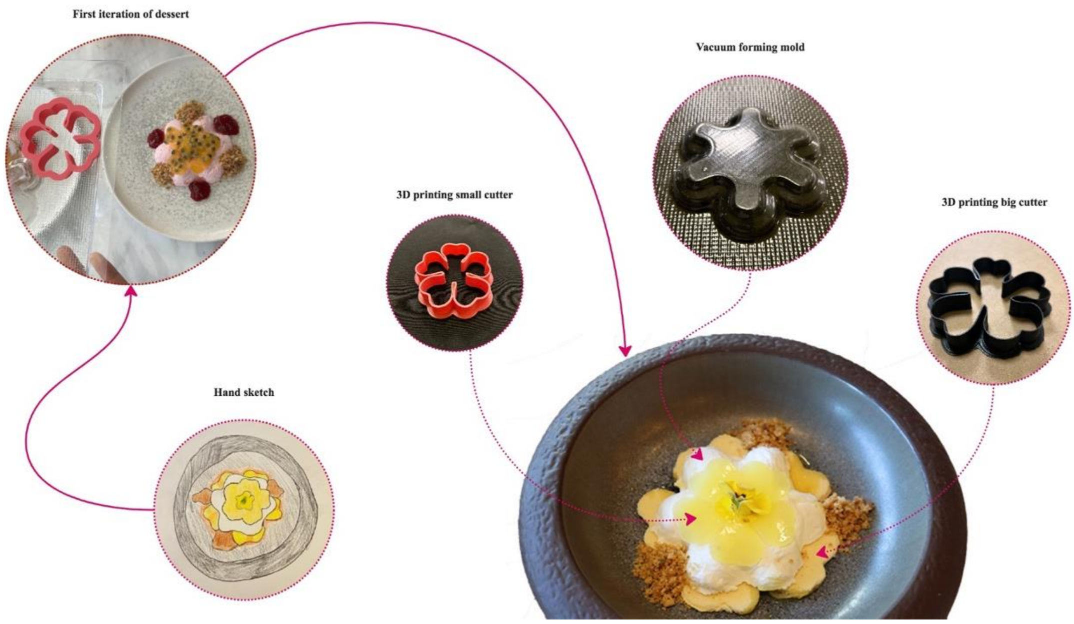
Figure 4.11 *Final Jury Dessert Plate, Sketch, and Associated Molds Used in the Production Workflow*



In another dessert example, three different digitally fabricated tools were used together: two 3D-printed cutters in different scales and a vacuum-formed mold (Figure 4.12). The larger cutter shaped the bottom cookie layer, while the lemon mousse was frozen inside the vacuum-formed mold, and finally, a smaller cutter was used to portion the orange gel garnish placed on top. Through multi-scale production of the same geometry, the student explored systematic variation and cohesive visual language across components.

These examples illustrate that when students chose to integrate multiple digital fabrication techniques, they did so strategically, connecting form coherence, food behavior and plating logic. While cross-method combinations appeared in only a limited number of final plates, their successful application demonstrates a growing maturity in linking design intent with gastronomic execution.

Figure 4.12 *Final Jury Dessert Plate, Design Process, and Associated Molds Used in the Production Workflow*



4.3 Findings From the Thematic Analysis of Focus Group

This thematic analysis is based on data collected from a focus group conducted with chefs and senior-year gastronomy students, aiming to understand experiences related to design-oriented learning and the integration of digital fabrication technologies in culinary education. In alignment with the study's design-based learning and digital prototyping framework, the analysis explores the creative strategies developed by participants throughout the process, the technical and conceptual challenges they encountered, their design-oriented ways of thinking, and their professional projections for the future.

By examining recurring patterns and shared meanings within the discussion, the analysis provides a holistic interpretation of how design and technology reshape gastronomic production practices. Considering both student and chef perspectives together offered a multifaceted understanding of the pedagogical, creative, and professional dimensions of technological learning. This approach further illuminated the emerging roles, production dynamics, and learning spaces situated at the intersection of design and gastronomy.

The findings are presented under four main themes, each representing a distinct dimension of how design and technology influence participants' ways of thinking, producing, and envisioning their professional futures.

4.3.1 Theme 1: Understanding Meaningful Gastronomic Design Through Flavor, Function, and Narrative

This theme illustrates how focus group participants approached gastronomy not merely as a technical domain but as a design practice situated at the intersection of aesthetics, functionality, and narrative meaning. The findings show that both chefs and students viewed digital fabrication tools, such as mold design, silicone casting, vacuum forming, and 3D modeling, not only as instruments for enhancing visual appeal but as mechanisms for reinforcing the conceptual coherence and expressive potential of a dish.

Rather than treating design as decoration, participants emphasized its role in shaping the identity, communicative value, and experiential depth of the gastronomic creation.

Participants described design as a process through which the plate becomes a narrative medium, enabling the alignment of form and flavor while making the chef's creative identity visible. This understanding aligns with earlier thematic analysis findings, particularly the theme of *"Creative Presentation Through Innovative Plate Design,"* reinforcing the notion that design functions as an expressive, communicative, and strategic tool within professional gastronomy.

Overall, this theme demonstrates that participants regarded design not as an ornamental enhancement, but as a meaning-making process that enriches the gastronomic experience. This main theme is divided into two sub-themes: (1) Personal Creativity and the Expression of Chef Identity, and (2) The Culinary Role of Mold Design and Its Relationship to Professional Practice.

4.3.1.1 Personal Creativity and the Expression of Chef Identity

This sub-theme highlights how participants perceive the design process as a means of expressing their creative identity, stylistic preferences, and culinary philosophy. In this sense, design is not merely a technical skill but is closely connected to personal aesthetics, professional vision, and the aspiration to create signature dishes.

Students described design practices as a space in which they could cultivate their own gastronomic identities in their future careers. As S14 emphasized the desire to create unique dishes, stating, *"I would like to create my plate… surprise the guest"* (S14), creativity and subjective interpretation emerge as central motivations. Similarly, Luca noted that presentation serves as a direct medium of communication with the customer, explaining, *"Presentation is the way you communicate with the guest"* (C1). This perspective reinforces the idea that design functions not only as a formal visual element but also as an emotional and experiential channel of communication.

The focus group data further demonstrate that design processes play an important role in the formation of chef identity. Participants indicated that distinctive presentation styles make both a chef's aesthetic perspective and creative competence visible within the kitchen. These findings align with earlier results in the thesis emphasizing "design as self-expression." In particular, students' ability to produce their own molds, develop unique aesthetic languages through digital tools, and pursue originality in professional kitchen settings underscores the importance of creative identity construction within gastronomy.

4.3.1.2 The Gastronomic Role of Mold Design and Its Relationship to Professional Practice

This sub-theme demonstrates that mold design is viewed by focus group participants not merely as an aesthetic tool, but as a functional component that enhances the meaning, structure, and overall experience of a dish. Participants emphasized that for design to create value in gastronomy, the chosen form must be aligned with the dish's ingredients, flavor profile, and overarching concept.

Drawing on professional kitchen experience, student S14 criticized molds used solely for decorative purposes and highlighted the importance of integrating molds holistically into the dish, stating: *"They use a sheep mold… I don't want that… I want to use the mold like it is a part of the dish, not something beautiful only."* (S14) This perspective underscores that molds should not function as superficial visual add-ons but as elements that contribute to the narrative and flavor architecture of a dish.

Chefs expressed similar views, particularly criticizing purposeless decorative use of molds. C2 remarked, *"Molds have been misused... decoration,"* highlighting that design in a professional kitchen should not become detached from functionality. C1 reinforced this point, stating, *"Everything needs to have a purpose and bring value to the dish,"* emphasizing intentionality and contribution as core principles of culinary design.

These findings align with the earlier thematic analysis that conceptualized plate design as a narrative medium. The focus group data indicate that mold design in gastronomy is positioned not merely as a formal or visual contribution, but as a functional design tool that supports flavor, technique, and narrative coherence.

4.3.2 Theme 2: Design Process and Creative Production Dynamics

This theme explores how focus group participants initiated, developed, and materialized their gastronomic design processes through digital fabrication tools. The findings indicate that design was not experienced as a linear sequence of steps, but rather as a flexible and iterative process shaped by sources of inspiration, material characteristics, and digital production techniques. Participants emphasized that their design decisions were guided by visual research, professional kitchen experience, and the interaction between ingredients and conceptual themes, illustrating that creative production in gastronomy involves both exploration and problem-solving.

This perspective aligns with earlier thematic analysis findings, particularly those under *"Design-Based Practices & Evolution of Creative Processes,"* showing that design in gastronomy is understood not as a fixed technical procedure but as a dynamic mode of thinking. This main theme is divided into two sub-themes: (1) Sources of Inspiration and Creative Translation in the Design Process, and (2) Gastronomic Design Flow: Starting Points and Process Development.

4.3.2.1 Sources of Inspiration and Creative Translation

This sub-theme examines the reference points participants draw upon when developing design ideas, and how these inspirations are translated into gastronomic outputs. The findings show that chefs and students frequently relied on visual research, professional experience, and digital platforms as active components of their creative process.

Students often began their design work by exploring visual platforms such as Pinterest and converting the images they found into digital sketches. As S14 described, *"I searched paintings, photos from Pinterest… then made it 3D."* S10 similarly drew on internship experiences to reinterpret existing designs: *"I used my internship experience… I recreated a design I saw in a restaurant."*

Chefs emphasized the role of real-world observation and contextual stimuli. C1 highlighted that creative ideas frequently emerge from practical encounters and sensory awareness, noting, *"Ideas come from a moment of observation or inspiration."* These accounts show that design in gastronomy is grounded in both visual research and the situated knowledge accumulated through professional practice.

The findings indicate that participants did not merely replicate external references but selectively adapted them to align with culinary requirements such as flavor logic, structural integrity, and functional coherence. This process mirrors earlier findings on "ideation and sketching based on external references," reinforcing the interdisciplinary nature of the design process.

4.3.2.2 The Flow of Gastronomic Design: Starting Points and Development

This sub-theme focuses on how participants initiate their design process and develop ideas into structured design outcomes. The findings show that gastronomic design does not follow a fixed sequence; instead, participants move flexibly between material-driven and concept-driven approaches. This variability highlights the cyclical and adaptive nature of the design flow.

Many students reported that they begin by identifying the core ingredient or recipe, allowing the dish itself to guide subsequent design decisions. S14 articulated this clearly: *"I wanted to take the food first, then the design."* S27 similarly noted, *"I decide the recipe first,"* while S15 described using a specific ingredient, lemon, as the foundation of the design process.

In contrast, some chefs emphasized the reciprocal relationship between concept and material. C1 explained that design sometimes emerges from a conceptual idea that subsequently shapes the dish: *"I think of the dish first and then the presentation."* This illustrates the two-way interaction between conceptual thinking and culinary execution.

These findings show that gastronomic design operates as an iterative and flexible problem-solving structure rather than a linear workflow. Participants integrate both material- and idea-based starting points, refining their concepts through digital tools and hands-on experimentation. This resonates with earlier findings on "the iterative creative process based on material–form interaction," positioning gastronomic design as a dynamic ecosystem shaped by creative intentions as well as the material and functional requirements of the dish.

4.3.3 Theme 3: Technical Learning Experience and Adaptation to the Production Process

This theme examines how participants adapted to digital design tools, the technical challenges they encountered, and the trial-and-error practices that emerged during production. The findings reveal that technological learning was initially demanding; however, through repetition, external support, online tutorials, and hands-on practice, participants progressively became more comfortable with these tools. In the prototyping phase, material thickness, mold geometry, and recipe compatibility were found to be critical determinants of functional design outcomes.

These insights parallel earlier analyses, especially the themes *"Challenges about the Process"* and *"Navigating Technological Challenges,"* demonstrating that mastering digital fabrication involves not only cognitive learning but also technical adaptation. This main theme is divided into two sub-themes: (1) Challenges and Adaptation Strategies in the Technological Design Process, and (2) Usability, Trial-and-Error, and Functionality in the Prototyping Phase.

4.3.3.1 Challenges and Adaptation Strategies in the Technological Design in Process

This sub-theme focuses on the technical difficulties participants encountered when learning digital design tools (e.g., Fusion 360, tablet applications) and the strategies they used to overcome them. The findings show that both students and chefs initially approached technology with hesitation or uncertainty, but gradually adapted by relying on online tutorials, instructor support, and repeated experimentation.

S14 summarized the learning curve by stating, *"Fusion 360 was hard… I needed help,"* while S10 explained, *"At the beginning it was too hard… watched lots of videos."* Technical limitations also influenced the process, as illustrated by S27's experience with device incompatibility: *"I couldn't find the app for my tablet."* These accounts demonstrate that adaptation to digital design tools relied on a combination of self-directed learning and guided assistance. C3 also highlighted the steep learning curve and the need for repeated assistance, stating, *"At the beginning it really was really hard… two, three* *times here as well to get your help,"* and later adding, *"but still I need again your help."* These reflections emphasize the continued reliance on expert guidance during the early stages of technological adaptation.

Overall, the findings highlight that the learning curve in digital design is natural and becomes manageable through sustained engagement. This sub-theme aligns with earlier results on navigating technological challenges, positioning participants' interaction with technology as an evolving practice strengthened by persistence and support.

4.3.3.2 Usability,Trial-and-Error, and Functionality in the Prototyping Phase

This sub-theme examines how participants tested their molds and forms during the production stage, the technical issues they encountered, and the solutions they developed. The findings show that gastronomic prototyping extends beyond visual creation to include evaluating material durability, thickness adjustments, recipe compatibility, and ease of use.

S10 reflected on the need for technical refinement, stating, *"The first design was too thick… I created it again,"* while S15 emphasized functional alignment between mold and recipe: *"It didn't work… wrong recipe for that mold."* C1's response to fragile design elements, *"Arms were too thin… maybe a two-piece mold"* demonstrates a professional-level approach to technical problem-solving. C3 contributed important technical insights based on iterative experimentation. He noted that overly thin forms often fail structurally, saying, *"If we make it too thin, it doesn't work… we might need at least five millimeters."* He also emphasized the necessity of conical geometry in vacuum forming: *"When you do this modeling or vacuum modeling, it should be a little bit conical… if it's like this, you* *have no chance."* Reflecting on cumulative learning, he added, *"We have now experience… mistakes you will not do anymore."*

These insights show that prototyping requires not only digital competence but also the ability to assess material–form interaction and resolve practical constraints. Consistent with earlier findings on iterative cycles and problem-solving strategies, participants continuously tested, revised, and improved their designs, positioning prototyping as a dynamic and evaluative design practice.

4.3.4 Theme 4: Future Perspectives and Professional Transformation in Gastronomy

This theme focuses on participants' views regarding the future role of design and digital production technologies in gastronomy. The findings highlight that digital design competencies hold the potential to transform not only creative production but also kitchen organization, professional roles, and branding strategies within the culinary field. Both chefs and students emphasized the long-term value of digital tools for personalized production, visual identity creation, and innovative presentation techniques.

This forward-looking perspective is consistent with earlier content analysis findings such as *"Feeling Prepared for the Future"* and *"Competency Development,"* indicating that technology is becoming a central domain of innovation in gastronomy. This main theme is divided into two sub-themes: (1) Future Conditions and Potentials, and (2) Future-Oriented Potentials of Design and Technology Learning.

4.3.4.1 Future Scenarios and Potentials: Technological Transformation, New Roles, and Professional Evolution

This sub-theme explores participants' expectations regarding the long-term impact of digital design and production technologies on the gastronomic sector. Findings indicate that digital tools may influence not only creative processes but also kitchen organization and professional role structures.

C1 highlighted the possibility of new professional roles emerging in the industry, stating, *"Hotels may have 3D designer positions in the future."* This reflects the potential formalization of design-oriented roles and increased collaboration between chefs and specialized designers. C2 contextualized this development within a broader technological evolution in the kitchen, noting, *"Technology evolves… like ovens, vacuum, now 3D printing,"* framing these changes as part of a continuous trajectory of innovation.

Participants emphasized that design-driven production could create new strategic opportunities for personalization, branding, and presentation aesthetics in gastronomy. These insights correspond with earlier thematic and content analyses related to *Integration of Digital Fabrication in Culinary Practices* and *Future Preparedness*, highlighting how design may become a strategic competency within professional kitchens.

4.3.4.2 Future Potentials of Design and Technology Learning

This sub-theme focuses on participants' perceptions of how design and digital production competencies will contribute to their long-term professional growth. Students and chefs described technological literacy as a vital future-oriented investment that will strengthen both creative and technical expertise.

S10's statement,*"After 5–10 years, we can create molds like a professional"* illustrates a belief that continued engagement with digital tools will yield expert-level proficiency. Participants emphasized that working with digital tools fosters not only technical ability but also creative confidence, enabling more personalized and innovative production in professional kitchens.

These findings reinforce those from earlier analyses on *Developing New Competencies*, demonstrating that design learning is viewed not merely as a course requirement but as a capacity that will support creative leadership, personalized production, and innovation in the future. Overall, participants framed digital design skills as an emerging domain of professional specialization with expanding relevance in the culinary field.

5. DISCUSSION

5.1 Rethinking Culinary Education Through Design-Based and Technology-Integrated Practices

The findings of this study show that integrating design-based practices and digital fabrication technologies into gastronomy education shifts learning from a traditional technique-centered, master–apprentice model toward a creative, exploratory, and innovation-driven pedagogical structure. This reframing positions gastronomy not only as a craft but as an interdisciplinary design practice, expanding beyond repetition-based professional training models and aligning with prior work that emphasizes the role of design thinking in conceptual reasoning, aesthetic development, and interdisciplinary problem-solving (Antlej et al., 2017; Cankül, 2019; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024; Mitchell et al., 2013; Seyitoğlu et al., 2025).

Both thematic and content analyses reveal that students engaged in ideation, visual research, sketching, CAD modeling, and prototyping alongside kitchen-based exploration, treating cooking as an iterative design inquiry rather than a purely technical task. Shared "Inspiration" folders and moodboards enabled the construction of visual narratives, exploration of form–function relationships, and articulation of cultural and personal references through gastronomic concepts, reflecting studio-based design logic commonly found in product and interaction design disciplines (Byrne, 2022; Deng et al., 2021; Kutlusoy, n.d.; Murakami & Lehrer, 2022). Focus group findings further demonstrate that participants regarded design as a narrative and communicative medium, *"a way to communicate with the guest"* highlighting that presentation functions not as decoration but as a channel for expressing meaning, emotion, and identity.

The hybrid learning environment, which intertwined kitchen practices with Openfab/FabLab spaces, facilitated a new mode of “culinary studio practice.” Students moved fluidly between food experimentation and digital prototyping, forming a bidirectional feedback loop: material food behaviors informed digital modeling decisions, while fabrication outputs influenced recipe adaptation and plating strategies. Tools such as 3D printers, laser cutters, vacuum-forming machines, silicone casting methods, and 3D scanning systems served not only as production devices but also as cognitive design tools that enabled rapid externalization, variation generation, and hypothesis testing (Damsbo-Svendsen et al., 2022; Lee et al., 2017; Lee et al., 2019; Weiler, 2020; Dolejšová et al., 2020; Mizrahi et al., 2016). The focus group data enrich this perspective by revealing that students and chefs emphasized the importance of purposeful design. Participants strongly opposed the use of molds as superficial decorative elements, arguing that form should align with flavor, structural logic, and the conceptual meaning of the dish. Statements such as “everything needs to have a purpose and bring value to the dish” and critiques of purely ornamental molds underscore how digital fabrication pushed participants toward intentional, concept-driven design choices.

The study further demonstrates how students increasingly grounded their culinary decisions in design constructs, such as coherence, semantic communication, usability, and identity formation. Focus group insights show that students used digital tools to express personal creativity, develop signature styles, and articulate their emerging chef identities. Creating personalized molds and forms was described as an act of self-expression, reinforcing the narrative that the integration of digital fabrication facilitates the development of unique aesthetic languages within gastronomy. This aligns with the emerging hybrid role of the “chef–designer,” widely discussed in contemporary gastronomy (Deng et al., 2021; Gayler et al., 2022; Kutlusoy, n.d.; Zoran & Coelho, 2011).

Insights from chef interviews further reinforce this transformation. Chefs highlighted personalization, narrative construction, brand identity, and the expressive potential of digitally fabricated molds and stencils as defining components of contemporary gastronomy. Their perspectives reflect evolving industry expectations, which increasingly require digital literacy, creative adaptability, and proficiency in nontraditional fabrication methods (Knochel & Meeken, 2021; Sarıoğlan, 2013; Kasko, n.d.; Sweetapple & Warriner, 2017). These views closely mirror focus group perspectives, illustrating strong alignment between professional and learner interpretations of design as an essential, purpose-driven dimension of gastronomic creation.

In conclusion, integrating design thinking and digital fabrication into culinary education fundamentally redefines how students learn, create, and innovate. This integrated educational model not only enhances aesthetic and technical competence but also cultivates creativity, material literacy, iterative reasoning, and technology-driven innovation, which are key competencies in the rapidly evolving field of digital gastronomy.

5.2 Material Interaction and Iterative Practice in Culinary-Design Education

The findings of this study reveal that learning in digitally mediated gastronomy education unfolds not as a linear sequence but as an iterative, experimental, and materially responsive process. This aligns with prior research in design thinking, food design, and creative practice, which emphasizes that deep learning emerges through cycles of trial-and-error, prototyping, reflection, and refinement (Gayler et al., 2022; Kutlusoy, n.d.; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024).

Students navigated the design process through non-linear, iterative cycles in which ideation, digital design, prototyping, kitchen-based testing, recipe adaptation, and redesign continuously informed one another. Rather than following a fixed sequence, the process often required students to return to earlier stages, such as refining digital models, producing new fabrication outputs, or developing alternative prototypes, after kitchen-based testing, depending on how the food materials responded. This dynamic aligns with Schön's concept of "reflection-in-action," which describes how learners continually reshape their understanding through ongoing action and feedback (Schön, 1983). In this process, students moved beyond merely executing recipes and instead engaged in a continuous negotiation between their intentions, the material behavior of food, and the constraints of digital tools.

The primary triggers of the iterative cycles were not the inherent limitations of digital fabrication tools, but rather the developing competencies of students as they learned to use these tools. Factors such as overlooking critical design parameters, neglecting essential production details, or failing to consider how digital models should align with the requirements of the accompanying recipe directly influenced the process. Technical issues, such as the breakage of negative areas in laser-cut stencils, errors in 3D modeling details, miscalculated angles in vacuum-formed molds, or mismatches between positive and negative geometries in silicone casting, required students to revise their designs (Lee et al., 2017; Lee et al., 2019; Dolejšová et al., 2020; Mizrahi et al., 2016). These challenges align with concepts such as "tinkering," "debugging," and "material feedback," which are recognized as foundational components of maker pedagogy (Blikstein, 2013; Resnick & Rosenbaum, 2013).

Focus group findings further deepen this understanding by illustrating how participants' iterative cycles were guided by multiple sources of inspiration, practical reasoning, and real-time problem solving. Students explained that they frequently moved back and forth between visual research, conceptual decisions, and material constraints sometimes starting with the recipe ("I decide the recipe first") and other times beginning from a visual or conceptual idea ("I searched paintings, photos… then made it 3D"). These accounts highlight that iteration did not emerge merely from technical errors but from an ongoing interpretive process shaped by aesthetic intentions, material behaviors, and professional experiences.

Iterative cycles were not limited to digital models; similar processes emerged in food preparation and recipe development as well. Kitchen-based issues, such as gels that failed to release from molds, chocolates that fractured during vacuum-molding demolding, or tuile mixtures that lost their shape due to silicone molds stiffening under heat, prompted students to adjust recipe components, modify stabilizers, or revise cooking techniques. This demonstrates that material literacy in gastronomy requires careful attention not only to the constraints of digital tools but also to the physical and chemical behaviors of food materials (Craft Yapı, n.d.; Mayku, n.d.-a; Miyatake et al., 2022; Eidler, 2024; Pengelly et al., 2012).

Participants in the focus group also emphasized that their iterations were shaped by technical usability concerns, such as mold thickness, conical geometry, and structural durability, which they discovered only after hands-on testing. Statements like "first design was too thick… I created again" and "if it's too thin, it doesn't work" demonstrate how iterative cycles were driven by practical evaluations of functionality. These reflections show that iterative reasoning emerged as both a creative and technical competency, formed through repeated material encounters.

This study revealed two distinct design workflows, mold-to-food and food-to-mold, yet the differences in these starting points did not alter the inherently iterative and adaptive nature of the overall design process. Technical constraints, material behavior, kitchen conditions, evolving skills, and aesthetic goals consistently required students to revisit and revise their decisions, regardless of their initial approach. As a result, both workflows progressed through cycles of continuous refinement, characterized by ongoing feedback, redesign, and adjustment. This finding aligns closely with the Design-Based Research (DBR) framework, which emphasizes cyclical improvement through iterative loops of designing, implementing, evaluating, and redesigning (Design-Based Research Collective, 2003).

Insights from chef interviews confirm that professional kitchens engage in similar cycles of iteration. Chefs noted that material unpredictability, tool limitations, and rapid experimentation are intrinsic to culinary innovation, and that accidental discoveries often drive creative breakthroughs (Knochel & Meeken, 2021; Sarıoğlan, 2013; Sweetapple & Warriner, 2017; Weiler, 2020).

In conclusion, this study demonstrates that iteration and problem-solving are not merely supplementary techniques within digitally mediated gastronomy education, but constitute the very essence of the learning process itself. By navigating the interplay between the technical constraints of digital tools, the behavior of food materials, and their own aesthetic goals, students developed a multidimensional learning practice that deepened their creative, technical, and cognitive capacities. Focus group insights further reveal that students themselves recognized this iterative movement as the core mechanism through which they refined ideas, solved problems, and translated inspiration into functional gastronomic forms. This finding provides a strong conceptual grounding for why design-oriented instructional approaches are critical within contemporary culinary education.

5.3 Developing Technical and Professional Competencies in Digital Gastronomy

The findings of this study show that working with digital fabrication technologies enabled culinary students to develop not only technical skills but also design literacy, material sensitivity, and professional awareness. Digital tools operated as cognitive mediators that shaped how students approached problem-solving, made decisions, and constructed their emerging professional identities (Dolejšová et al., 2020; Mizrahi et al., 2016; Vogel et al., 2021; Lee et al., 2017; Mayku, n.d.-a; Miyatake et al., 2022).

Across the semester, students produced more than 150 prototypes using laser cutting, 3D printing, silicone casting, vacuum forming, and 3D scanning. This aligns with maker pedagogy principles, where learning emerges through active making and reflection. Each tool supported different dimensions of learning:

- Laser cutting strengthened 2D thinking and material management;
- 3D printing supported volumetric reasoning and manufacturability awareness;
- Silicone casting developed understanding of positive/negative geometry;
- Vacuum forming fostered awareness of draft angles and deformation;
- 3D scanning introduced scale, texture, and geometry considerations.

Focus group findings reinforce that adapting to these technologies involved an initial steep learning curve. Participants frequently described early difficulty, especially with CAD tools ("Fusion 360 was hard… I needed help") and device limitations, yet emphasized that practice, tutorials, and instructor guidance gradually increased their confidence. Chefs reported similar needs for repeated assistance, underscoring that technological adaptation requires sustained engagement.

Technical competence developed most strongly during prototyping, where students assessed usability and iteratively refined their designs. Participants highlighted the importance of adjusting mold thickness ("first design was too thick… I created again"), ensuring structural stability ("if it's too thin, it doesn't work"), and experimenting with geometry based on real-world performance. These reflections show that students learned to identify functional problems and respond with informed design revisions.

As students gained control over digital production, they began envisioning broader professional applications. This aligns with Gastronomy 4.0 literature, which positions digital literacy and innovation capability as essential competencies in contemporary culinary practice. Focus group data show that students perceived digital fabrication as a long-term professional investment, expressing confidence that they would "create molds like a professional" and use custom tools to develop distinctive presentations.

Insights from chefs further support this transformation. They emphasized digital fabrication as a "differentiating skill" that enhances competitiveness in modern kitchens, and noted that cumulative hands-on experience, "mistakes you will not do anymore" is central to attaining professional-level mastery.

In sum, digital fabrication fostered technical proficiency, design-oriented reasoning, material literacy, and creative confidence. The combined findings show that technology integration does not simply teach new tools but actively supports the emergence of mature, adaptable, and innovation-driven culinary professionals.

5.4 Crafting the Chef-Designer Identity: Professional Transformation in Digital Gastronomy Education

This study demonstrates that as students engage with digital fabrication technologies and design-oriented processes, they begin to experience gastronomy not merely as a culinary practice but as a multidimensional domain in which personal expression, technical mastery, and creative identity formation intersect. The competencies and experiences gained throughout the process become instruments that students can draw upon in constructing a new professional identity. This transformation aligns with contemporary gastronomic discourse, in which chefs are increasingly expected to blend artistic authorship, material experimentation, and digital proficiency (Lee et al., 2017; Mayku, n.d.-a; Miyatake et al., 2022; Sweetapple & Warriner, 2017; Zoran, 2025).

Across the findings, three interrelated dimensions of identity development clearly emerge. Creative confidence: Students who initially struggled with CAD and digital modeling gradually gained confidence as they experimented, iterated, and produced functional tools. Over time, this process shifted their self-perception from tentative beginners to capable creators. Professional awareness: Students increasingly recognized technological competence as a strategic advantage in modern gastronomy and expressed a desire to use digital fabrication tools in their future restaurants. Identity transformation: Students began to see themselves not only as chefs-in-training but also as designers, creators, and innovators who can shape personalized culinary tools, develop distinctive aesthetics, and construct narrative-driven presentations.

Focus group findings further reinforce this identity shift, showing that students viewed design as a direct extension of personal creativity and self-expression. Some of the participants described the presentation as “a way to communicate with the guest,” and emphasized the desire to “surprise the guest” by creating unique forms that reflect their individual style. Producing custom molds, reinterpreting visual inspirations, and translating conceptual ideas into physical artifacts enabled students to articulate their creative intentions more clearly, strengthening the connection between aesthetic authorship and professional identity.

The prototypes produced by the students and the dishes they created using these outputs further illustrate this transformation. Their consistent use of digitally fabricated stencils and molds, both in final jury presentations and in practical kitchen coursework, indicates that these technologies were embraced not merely as production instruments but as mediums of personal expression and professional representation. In this way, digital fabrication technologies have become both an aesthetic and functional component of students’ emerging gastronomic identities.

Insights from the chef interviews reinforce this shift. Chefs emphasized that contemporary gastronomy now requires not only cooking proficiency but also multidimensional competencies such as creative direction, concept development, narrative construction, and technological adaptation (Knochel & Meeken, 2021; Sarıoğlan, 2013). They also noted that, alongside traditional kitchen equipment, there is an increasing need to build a new type of “toolbox” that incorporates digital fabrication technologies, signaling a redefinition of professional skill sets in the field. This perspective directly aligns with focus group discussions in which participants anticipated the emergence of new professional roles and technological specializations within gastronomy, suggesting that the chef-designer identity is not merely an educational outcome but reflects an evolving trajectory within the industry itself.

Students also articulated a long-term professional strategy anchored in design-based production. They recognized that the ability to independently design molds, cutters, and stencils enables them to craft unique presentations, strengthen brand identity, and deliver multisensory experiences. This aligns with the “chef as designer” framework highlighted in recent literature, which positions chefs as creative authors who engage deeply with form, materiality, and expression (Eidler, 2024; Wang et al., 2024).

Taken together, the combined data reveal that the chef-designer identity emerges not only from technical mastery but from the integration of personal creativity, purposeful design reasoning, and future-oriented professional aspirations, elements consistently highlighted by both students and chefs in the focus groups.

In conclusion, this study demonstrates that the integration of digital fabrication and design thinking fosters the emergence of the chef-designer, a hybrid professional identity characterized by creativity, technical mastery, and digital fluency. These findings underscore that design-based and technology-integrated approaches in gastronomy education not only enhance students’ skills but also actively shape their identity, vision, and future career trajectories, preparing them for the evolving landscape of digital and experiential gastronomy.

5.5 Implications for Gastronomy Education, Human-Food Interaction, and Digital Gastronomy

This study demonstrates that the integration of design-oriented educational approaches and digital fabrication technologies into gastronomy education generates multifaceted impacts on both learning outcomes and the future of the culinary profession.

The findings indicate that gastronomy education is evolving beyond a domain centered solely on technical skill acquisition, moving instead toward a hybrid educational ecosystem that brings together creativity, technological adaptability, experience design, and material engagement (Gayler et al., 2022; Kutlusoy, n.d.; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024).

5.5.1 Implications for Gastronomy Education

The results of this research reveal a need for a paradigm shift in culinary training: from technique-centered instruction toward a design-infused educational model. The integration of digital fabrication and iterative design practices positions culinary learning within a studio-based framework, where experimentation, material inquiry, and conceptual reasoning play as central a role as practical kitchen skills.

Focus group insights further reinforce this shift, as participants emphasized that design provides a platform for personal expression, purposeful form-making, and coherent alignment between flavor, structure, and concept. Students' insistence that molds must "bring value to the dish" highlights the educational importance of teaching design not as decoration, but as functional and narrative coherence.

Moreover, the findings imply that design literacy, including critical reflection, aesthetic reasoning, and intentional form-making, should be considered an essential component of contemporary culinary education (Schön, 1983; Blikstein, 2013). Programs that fail to integrate these competencies risk leaving students underprepared for an industry increasingly shaped by personalization, multisensory design, and technological fluency.

5.5.2 Implications for Human-Food Interaction (HFI)

The study contributes to HFI by expanding its conceptual scope beyond consumption-oriented or sensory-focused perspectives. By demonstrating how students simultaneously manipulate edible materials and digital tools, the research highlights food–tool co-evolution, where food serves not only as an interface for interaction but as a dynamic design material shaped through technological mediation (Gayler et al., 2022; Kutlusoy, n.d.; Damsbo-Svendsen et al., 2022; Eidler, 2024; Gonera et al., 2024).

The focus group data support this reframing by showing that students' design decisions were continually negotiated through material behavior, digital tool constraints, and iterative adjustments, illustrating the deeply interactive and embodied nature of gastronomic production. This suggests that HFI must more fully consider the productive dimension of food interaction, acknowledging how tools, materials, and design intentions shape each other during the act of creation.

5.5.3 Implications for Digital Gastronomy

This research fills an important gap in the field by providing a longitudinal integration model for digital gastronomy education. Unlike prior short-term or tool-specific studies, the multi-semester approach demonstrates how students develop hybrid creative–technical competencies over time and how digital tools evolve from unfamiliar instruments into cognitive scaffolds that shape concept development, decision-making, and self-perception (Zoran & Coelho, 2011; Zoran & Cohen, 2018). A key implication is the emergence of the chef-designer identity, a hybrid professional role where creativity, technical mastery, and digital proficiency intersect.

Focus group findings further reinforce this transformation by showing that students viewed digital tools not merely as technical instruments but as integral components of their future professional identity. Participants emphasized that digital fabrication may create new roles within the sector (e.g., “hotels may have 3D designer positions”) and that personalized production has the potential to strengthen brand identity and creative authorship in professional kitchens.

Collectively, the study indicates that digital gastronomy is not merely about the adoption of new tools; it represents a broader disciplinary transition toward design-driven, technologically augmented forms of culinary creativity.

6. LIMITATIONS

Several limitations should be considered when interpreting the findings of this study. First, the research was conducted within the context of a single university. Although the institution offers advanced kitchen facilities and access to a FabLab environment, the results reflect pedagogical, structural, and cultural characteristics specific to this setting. Therefore, the transferability of the findings to programs with different educational structures, resource capacities, or institutional philosophies may be limited.

Second, data were collected only from the 27 students enrolled in the fourth implementation of the course. Although the course was offered across four semesters, each semester involved different groups of students who graduated at the end of the term, making it impossible to follow the same cohort longitudinally. As a result, it was not feasible to conduct a cross-semester developmental analysis of students' learning progress. The course was iteratively refined over three semesters and the fourth semester served as the final iteration; however, basing the dataset solely on this final version prevented comparative analysis across earlier iterations.

Third, in the early semesters during which the course was developed and iterated, access to digital fabrication tools and materials was occasionally limited. For example, oven-curable silicone and the 3D scanner were not always available in earlier terms. In contrast, during the fourth semester, when the data for this study were collected, there were no material or equipment constraints. While this allowed students greater freedom in their production processes, not all students used the digital fabrication technologies to the same extent or with the same level of engagement, which may have created both affordances and limitations in their learning experiences.

Focus group findings support this limitation, as participants frequently described early challenges with learning CAD (e.g., “Fusion 360 was hard… I needed help”), device constraints, and the need for repeated guidance before gaining confidence. These reflections indicate that time pressure and the format of digital instruction played a meaningful role in shaping learning outcomes.

Fourth, the temporal structure of the course and the students’ initial proficiency levels introduced additional constraints. The digital design component of the course relied largely on asynchronous, video-based learning, with only a single one-hour face-to-face introductory session. Consequently, students were required to develop their CAD and digital modeling skills primarily through self-directed learning. The course was scheduled immediately after a kitchen practice session and delivered within a one-hour time frame, necessitating the introduction of multiple technologies in a single session. This structure resulted in certain techniques, particularly 3D scanning and advanced CAD modeling, being covered only superficially. Students’ limited prior experience with digital modeling further accentuated the steep learning curve, affecting the pace, depth, and overall quality of their outputs. Although all students acquired foundational digital design skills by the end of the semester, the intensive nature of this learning process and the temporal constraints were influential factors shaping their experience.

Fifth, the researcher served simultaneously as the course designer, instructor, and data collector, resulting in partial overlap between instructional and research roles. While this introduces potential bias, such positionality is common in qualitative research and provides meaningful advantages: close observation of the learning process, deep understanding of participant experiences, and comprehensive insight into the dynamics of the course. The study employed structured evaluation criteria, multiple data sources, and systematic documentation to mitigate potential subjectivity. Thus, although the researcher's multiple roles constitute a limitation, they also enriched the contextual depth and quality of the data.

Sixth, interviews with chefs were conducted with only three participants. As these chefs were directly involved in the course, they provided contextually grounded professional perspectives; however, a larger group would have offered a broader diversity of viewpoints. Additionally, because digital fabrication technologies were relatively new for the chefs as well, they explored and experimented with these tools concurrently with the students. This concurrent learning process, while valuable for fostering a shared pedagogical environment, may have limited the extent to which the chefs could offer fully developed or long-term professional insights into the use of such technologies. Furthermore, one of the chefs who participated in the interviews did not attend the focus group session, reducing the diversity of professional perspectives represented in the group discussion and slightly limiting the balance between chef and student voices.

Another contextual limitation relates to the hierarchical structure characteristic of professional kitchen culture. The presence of chefs during the focus group may have influenced student participation, potentially causing some students to adopt a more reserved or deferential stance. This dynamic may have limited the openness, criticality, or depth of certain student contributions, reflecting how social hierarchy can subtly shape data collection outcomes in gastronomy-related qualitative research.

Finally, part of the dataset, particularly observational notes and jury evaluations, relies on qualitative judgments. Although predefined evaluation criteria were used and the final jury included two chefs in addition to the researcher, assessments in gastronomy inherently involve a degree of interpretation, which may introduce subjective influences.

Similarly, focus group participants noted that their evaluations of mold usability, aesthetic coherence, and functional success were shaped by personal preferences and experiential judgment, further highlighting the subjective nature of both learning processes and data sources.

In summary, while these limitations shape the scope of the study, they do not diminish the value of its findings. Instead, they highlight opportunities for future research to incorporate multi-site implementations, broader participant groups, varied technological infrastructures, and more independent evaluation processes. In this regard, this study provides a carefully contextualized foundation and a meaningful starting point for subsequent investigations in design-integrated and technology-enhanced gastronomy education.

7. FUTURE RESEARCH DIRECTIONS

The findings of this study reveal that the integration of digital fabrication tools and design-oriented thinking into gastronomy education requires an iterative and flexible learning model rather than a linear and fixed structure. The results indicate that such integration is more effectively achieved through an iterative and flexible learning model rather than a fixed and linear structure. The staged introduction of tools, the balance between kitchen-based production and laboratory work, and prototyping-oriented processes support students' exploratory learning while allowing for the management of cognitive load. The findings further suggest that digital technologies should be positioned not merely as auxiliary skills, but as integral components of gastronomic ideation, material experimentation, and experience design. This perspective points toward moving beyond traditional craft-based models in gastronomy education and toward the development of hybrid educational structures in which culinary practice is integrated with design literacy and technological competencies. Moreover, the study demonstrates that interdisciplinary, studio-based learning environments can support practice-oriented and reflective learning, indicating that similar pedagogical approaches may be transferable to other applied educational fields where material thinking and prototyping are central.

Taken together, these implications provide a reflective foundation for identifying future research directions that can further extend and contextualize the contributions of this study within gastronomy education and beyond.

Building on the findings and limitations of this study, several directions can be proposed for future research in design-integrated and technology-enhanced gastronomy education.

First, future studies may examine how this course model can be adapted across different institutions. Since each university or educational setting possesses its own pedagogical structures, infrastructural capacities, technological resources, and culinary culture, direct replication of the model may not be necessary. Instead, research could explore which components of the approach introduced in this study can be preserved, modified, or redesigned across varying contexts. Such adaptation-oriented investigations would offer a deeper understanding of how design and digital fabrication integration can be implemented and scaled across diverse institutional environments.

Second, repeating the final iteration of the course with new student groups and conducting comparative analyses between cohorts could help identify which elements of the course design most strongly influence student experience and learning outcomes. Additionally, follow-up interviews with graduates who previously completed the course would provide valuable insights into how the competencies gained are applied in professional settings, how they influence career trajectories, and how they translate into sectoral practices. This line of inquiry would contribute to a more comprehensive understanding of the long-term effects of design- and fabrication-based gastronomy education. Focus group findings suggest that students view digital competencies as long-term professional assets, indicating that future research could examine how these skills evolve over several years and how they shape emerging career identities such as the “chef-designer.”

Third, future research could revisit the breadth and depth of the technologies incorporated into the course. Given the limited use of the 3D scanner in this study, it would be meaningful to investigate how more structured and practice-oriented engagement with this technology influences learning outcomes. Likewise, the impact of additional face-to-face modeling sessions on students' ability to conceptualize and operationalize 3D modeling skills could be examined. Since CNC-based fabrication processes are currently unsuitable for kitchen contexts due to food safety constraints, research in this area would require the development of food-safe and hygienic solutions before such technologies can be integrated.

Fourth, studies employing co-design models that bring together chefs, educators, designers, and students may provide valuable insights into how different professional and academic stakeholders structure expertise, creativity, and technology-oriented decision-making processes within collaborative environments. The focus group discussions indicate that hierarchical dynamics can shape participation and idea exchange, suggesting that future studies should also investigate how power relations and professional hierarchies influence co-design outcomes in culinary settings.

Fifth, research grounded in Human–Food Interaction (HFI) frameworks could investigate how digital tools influence the multisensory and interactive dimensions of gastronomic creation. Examining how technologically shaped materials, surfaces, and forms affect dining experiences would strengthen the conceptual connection between digital gastronomy and experience design. Participants' emphasis on purposeful design, narrative construction, and communicating with the guest highlights the need for future studies that explore how digitally mediated forms shape experiential and emotional dimensions of dining.

Finally, future research could explore how the emerging "chef-designer" identity shapes career pathways, entrepreneurial practices, and innovation cultures within the culinary field. Such studies would deepen theoretical and practical discussions concerning the evolving creative–technical roles of contemporary culinary professionals.

Focus group insights indicating future industry roles such as “3D designer positions in hotels” point to the importance of examining how new professional specializations may emerge and how digital fabrication competencies might become formalized within culinary labor structures.

Taken together, these research directions offer a rich foundation for advancing the understanding of how design thinking and digital fabrication technologies can shape the future of gastronomic education and contribute to the evolving needs of the discipline.

8. CONCLUSION

This study demonstrates that the integration of design-oriented thinking and digital fabrication technologies into undergraduate gastronomy education can fundamentally transform how students learn, create, and position themselves within the evolving culinary profession. Over four iterative semesters, the course matured into a hybrid learning model in which digital tools, material exploration, and culinary practice converged to form a dynamic and creativity-driven environment. This process not only enabled students to acquire technical competencies but also allowed them to discover and shape their own design workflows, aligning these workflows with their creative intentions and personal working styles. Focus group findings reinforce this outcome by showing that students actively interpreted design as a means of personal expression, intentional form-making, and communicating with the guest, highlighting that the learning process supported both technical growth and expressive authorship.

A defining contribution of this research is the emergence of the “chef-designer” identity, a broadened professional profile that merges creative authorship, material literacy, technological fluency, and culinary expertise. Through engagement with CAD modeling, laser cutting, 3D printing, and mold-making techniques, students began to see themselves as creative actors capable of designing both the tools they use and the experiences they deliver. Working with digital tools enabled them to develop more imaginative menus, presentations, and cooking processes, opening up new aesthetic and technical possibilities. Participants’ reflections in the focus group highlight this identity shift, describing the desire to create unique forms, surprise guests, and pursue originality through personalized molds and digitally fabricated elements. These insights show that students not only learned new tools but internalized design as part of their emerging professional identity.

Throughout the course, students also learned to navigate challenges by generating alternative solutions, thereby strengthening their problem-solving and resilience skills. Notably, the chefs involved in the course were also active participants in this transformation, learning new digital tools alongside the students and expanding their own creative and technological repertoires, an outcome that highlights the broader educational and professional reach of the model. The parallel learning trajectory observed in both students and chefs illustrates how digital fabrication environments can democratize learning, temporarily softening hierarchical dynamics and fostering shared discovery.

The longitudinal structure of this study represents another key contribution. As one of the first models to integrate design and digital fabrication across multiple semesters in an undergraduate gastronomy program, it provides evidence-based insights into how such approaches evolve and stabilize over time. Additionally, the course stands as the first digitally enhanced gastronomy studio implemented at the bachelor's level, offering a framework that institutions with similar infrastructures may adopt, adapt, or reinterpret according to their own educational cultures. Rather than proposing a fixed curriculum, this study presents an adaptable learning model capable of being reshaped to suit diverse pedagogical and technological contexts.

The findings also show that design integration supports students' preparation for professional life. The course not only helped students develop technical skills but also facilitated collaborative menu creation, enhanced their ability to negotiate ideas within a team, and allowed them to practice essential competencies such as coordination, communication, and distributed responsibility, skills central to professional kitchen environments. Focus group participants additionally emphasized the long-term professional value of digital fabrication, anticipating future roles such as specialized 3D designers in hospitality settings and expressing confidence that continued practice would enable them to create molds "like a professional." Such insights highlight the expanding significance of digital literacy in shaping future culinary careers. By working with digital fabrication tools, students discovered new ways of practicing their future profession, strengthened their creative identities, and positioned themselves advantageously for emerging fields such as experiential gastronomy, fine dining innovation, and bespoke culinary production.

Taken as a whole, this research contributes to three interconnected fields: gastronomy education, by offering a hybrid pedagogical framework; Human–Food Interaction, by repositioning food as an active interface in creative production; and digital gastronomy, by presenting a rare, multi-semester integration model supported by empirical study. At a time when digital tools are reshaping culinary practice globally, this study provides a meaningful foundation for envisioning how design thinking and fabrication technologies can cultivate the next generation of chef-designers, professionals who navigate the intersection of craft, creativity, and technological innovation.

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APPENDICES

APPENDIX A. PARTICIPANT CODING AND DATA COLLECTION

Each participant was assigned a unique code to ensure anonymity. The table indicates which participants took part in each stage of the study, including surveys, interviews, and focus group sessions. This structure allows for a clear overview of participant involvement throughout the research process.

Figure A.1 *Participant Coding and Data Collection Matrix*

Participant Number	Gender	Pre-Survey	Post-Survey	Interview	Focus Group
S1	Female	☑	☑	☑	☐
S2	Female	☑	☑	☑	☐
S3	Female	☑	☑	☑	☐
S4	Male	☑	☑	☐	☐
S5	Female	☑	☑	☑	☐
S6	Female	☑	☑	☐	☐
S7	Male	☑	☑	☑	☐
S8	Female	☑	☑	☐	☐
S9	Female	☑	☑	☐	☐
S10	Male	☑	☑	☑	☑
S11	Female	☑	☑	☑	☐
S12	Female	☑	☑	☐	☐
S13	Female	☑	☑	☑	☐
S14	Female	☑	☑	☑	☑
S15	Female	☑	☑	☑	☑
S16	Female	☑	☑	☑	☐
S17	Female	☑	☑	☐	☐
S18	Female	☑	☐	☐	☐
S19	Female	☑	☑	☑	☐
S20	Male	☑	☐	☐	☐
S21	Female	☑	☑	☐	☐
S22	Female	☑	☐	☐	☐
S23	Female	☑	☑	☐	☐
S24	Female	☑	☑	☑	☐
S25	Female	☑	☐	☐	☐
S26	Male	☑	☐	☐	☐
S27	Female	☑	☑	☐	☑
S28	Male	☐	☑	☐	☐