Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #46974

Information Seeking and Sensemaking in Engineering Education: A Framework for Capstone Projects

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Abstract

The ACRL Research Planning and Review Committee described the top trends in academic libraries during 2024, drawing on research and initiatives from librarians across the profession, highlighting the constant change libraries face. Makerspaces and tech spaces are one of those top trends, fostering collaborations between engineering departments and academic libraries, creating opportunities for further exploration of learning styles and typologies of learning.

This paper introduces a study designed to extend already existing research on information seeking and sensemaking in engineering education by mapping the ACRL information literacy frameworks and engineering design lifecycle methodologies with alternative frameworks, such as Metaliteracy and Maker Literacy, that could be more appropriate to understand the nature of student learning experiences as they formulate and develop Capstone Projects, while assuming their roles of problem-solvers, metaliterate learners and "makers".

The results emerging from this research could guide librarians and instructors to identify specific competencies and professional skills that engineering students develop in relation to each stage of project development. Then, the selection of relevant information resources could promote meaningful learning experiences across disciplines.

Keywords: Information Literacy, Metaliteracy, Makers Literacy, Capstone Projects, Engineering Education

1. Introduction

Capstone Projects are a significant part of the engineering curriculum, providing students with opportunities to formulate and solve real-world problems, in collaboration with industry sponsors. These projects generally have interdisciplinary connections across areas such as engineering, education, business, medicine, social entrepreneurship, and more.

Traditional Senior Design Capstone Courses in engineering education suggest specific phases for a robust design process, such as problem definition, concept generation, preliminary design, detailed design, proof of concept and documentation [1,2,3], while only a few [4] guide students to the challenges of design standards, fabrication, commercialization and intellectual property regarding the resulting designs and procedures. More recent research [5,6] suggests that Science, Technology, Engineering, and Math (STEM) majors in higher education must also prepare students to access, explore and incorporate concepts and information from several disciplines as part of Capstone Projects.

As part of a research project exploring the nature of successful Capstone Projects in engineering education, this study was designed to map already existing information literacy frameworks and engineering design lifecycle methodologies, with alternative frameworks that could be more appropriate to understand and assess the nature of student learning experiences as they formulate and develop Capstone Projects.

The typologies that support the mapping process in this study were selected by the researcher to extend the research conducted by Nagle and Tzoc [7], exploring trends regarding innovation and experiential learning in academic libraries, where makers literacy is described as an emerging literacy that can be seen as a subset of metaliteracy, promoting a more student-centered idea of information literacy. Therefore, the literature review will describe: (a) the ACRL Framework for Information Literacy in Higher Education, characterizing information creation as a process and research as inquiry [8], (b) *metaliteracy,* conceptualizing students as active participants, effective communicators and translators of information [9], and (c) *makers literacy,* an emerging literacy enabling students to build self-efficacy, explore their entrepreneurial spirit, and learn skills that will last them long past their academic career [10].

2. Literature Review

Information literacy in higher education: The ACRL Information Literacy Competency Standards for Higher Education [11] state that information literacy is an intellectual framework for understanding, finding, evaluating, and using information, in relation to tasks and activities supported by information technology; it initiates, sustains, and extends lifelong learning through abilities involving diverse technologies, but are ultimately independent from them [11]. In 2015, a *Framework for Information Literacy in Higher Education* was introduced by the Association of College & Research Libraries out of a belief that information literacy as an educational reform movement will realize its potential only through a richer, more complex set of core ideas [8]. An in-depth understanding of information literacy skills and information behaviors is required to identify the barriers that frequently prevent users from accessing, understanding and using information relevant to their needs [12].

Metaliteracy: As a response to emerging types of media and media literacies, a reframing of information literacy is suggested by Mackey and Jacobson *as metaliteracy* [13] to support multiple literacy types, and to connect it to related literacy types addressing diverse types of emerging technologies and learning styles. From multiple literacy perspectives – digital literacy, media literacy, visual literacy and information technology fluency – *a metaliteracy perspective* tried to expand the scope of information literacy as more than a set of discrete skills, rethinking it as active knowledge production and distribution in collaborative environments. As an extended framework, metaliteracy provides an overarching and unifying framework to build on core information literacy competencies while advancing critical thinking and empowerment for producing, connecting and distributing information as independent and collaborative learners, moving knowledge acquisition beyond search and retrieval tasks [14].

A “metaliterate learner” is characterized by Mackey and Jacobson as an active participant, an effective communicator and translator of information, and an author of information in many forms, including web documents, visual material, aural materials, essays, presentations, annotations, and interactive communications [15]. Moreover, metaliteracy advances the idea that learner empowerment is achieved through the original creation of individual and collaborative artifacts in any constructive form. Metaliterate producers aspire to make meaning and communicate while engaging in multimodal learning environments [16].

The original metaliteracy model introduced by Mackey and Jacobson [15] provided an integrated approach to information literacy consistent with all the core elements of the ACRL standard definition – determine, access, evaluate, understand, incorporate and use – and included other

elements – collaborate, participate, produce and share [15]. A current metaliteracy model includes domains, characteristics and roles as core components, together with goals and learning objectives, as described below [16]:

- **Domains:** The four learning domains include affective, behavioral, cognitive and metacognitive
- **Characteristics:** The key characteristics of a Metaliterate Learner include adaptable, open, productive, informed, collaborative, participatory, reflective and civic-minded
- **Roles:** The Metaliterate Learner roles include collaborator, producer, publisher, researcher, participant, communicator, translator, author and teacher
- **Goals and learning objectives:**
    - Actively evaluate content while also evaluating one's own biases
    - Engage with all intellectual property ethically and responsibly
    - Produce and share information in collaboration and participatory environments
    - Develop learning strategies to meet lifelong personal and professional goals

Makerspaces: Known also as *makerlabs, hackerspaces* or *fablabs, makerspaces* vary from institution to institution, generally including diverse equipment to support educational activities, such as 3D printers, laser cutters, sewing machines, green screens, and much more [17]. The library is described by Mackey and Jacobson [16] as an ideal location for makerspaces because of the support provided for collaborative learning within shared academic settings. They also found that Maker-Centered Learning and makerspaces could be explored to identify connections and similarities between a Maker Literacy and Information Literacy [16]. Previous research on makerspaces in academic libraries by the Albertsons Library MakerLab team at Boise State University has identified three emerging trends [17]:

- The utility of makerspaces and their efficacy in academic libraries.
- The role of librarians while implementing and sharing best practices for makerspace services and policies.
- The educational aspects of makerspaces for instructional purposes and learning outcomes.

Like much of the literature on makerspaces in academic libraries, very little scholarship exists on instruction. The Albertsons Library MakerLab team at Boise State University [18] describes the ACRL Framework as "the embodiment of the maker spirit" and conducted a mapping process to explore how those frameworks match with their MakersLab learning environments; the results provided general insights for ways in which makerspaces and emerging technologies can support information literacy in higher education [18]. There is a need to further explore how academic librarians might integrate makerspaces into their instructional sessions.

Makers Literacy: Early efforts were reported to incorporate makerspaces into information literacy sessions and to explore ways to expand the idea of information literacy through "new literacies," such as creativity, innovation, and digital citizenship [19]. Other teams started exploring the development of maker-competencies supporting new literacies in academic library makerspaces [20]. Then, a team at the University of Arizona Libraries explored several Makerspace Resources, Services and Staffing Models for makerspaces targeting engineering students [21], while the Makerspace Team at the University of Texas at Arlington Library [10], in collaboration with other libraries, started exploring ways in which academic library makerspaces impact undergraduate student learning experiences, identifying best practices that

incorporate cross-disciplinary, transferrable ("transdisciplinary"), maker-based competencies into the undergraduate curriculum.

A set of Maker Literacy competencies are suggested by the Makerspace Team at the University of Texas at Arlington Library (Appendix B), to function as a tool for mapping transferable skills to subject-based learning outcomes, enabling instructors to make visible the learning acquired through project-based assignments and courses situating students as creators, applying competencies multiple times and not necessarily in a particular order [10]:

- Identify and articulate a need to create
- Analyze and explore ideas, questions, problems, and potential solutions
- Create effectively and safely
- Assess the availability and appropriateness of tools and materials
- Prototype using iterative design principles
- Develop a project management plan
- Engage in effective teamwork
- Employ effective knowledge management practices
- Apply knowledge gained into other situations
- Understand ethical and intellectual property issues surrounding making

Metaliteracy and Makers Literacy: Mackey and Jacobson [16] identified several connections and similarities between Metaliteracy and Maker Literacy - Metaliteracy considers metacognition in relation to the affective, behavioral and cognitive areas, while Makers Literacy reinforces metacognitive reflection that provides learners with meaningful insights about their own thinking and creative process. On the other hand, Nagle and Tzoc [7] consider that Metaliteracy places emphasis on learners as active, collaborative and reflective creators, which aligns with the goals of Maker Literacy to develop creative producers. They also compared Metaliteracy to Makers Literacy since it supports learners in critically evaluating their world while gaining the confidence to contribute to it with their original creations. In the same way that Metaliteracy prepares learners to develop *a Metaliteracy Mindset* through metacognitive reflection and informed participation, Nagle and Tzoc emphasize that Makers Literacy encourages learners to be reflective as well [7].

There is a need for further research to understand the connections, similarities and intersections across frameworks for specific learning goals, to better support and scaffold research, innovation and learning experiences of engineering students participating in Multidisciplinary Capstone Projects.

3. Procedures

Research design: There is a tendency in academic libraries to use qualitative research to address issues related to information seeking, information use, and communication behavior by information users in natural settings [12]. This study is based upon a qualitative research paradigm [22,23,24,25], since it focuses on understanding the connections, similarities and intersections across frameworks representing diverse approaches to formulate and develop successful Capstone Projects in the context of Engineering Education. The emerging results are based on the analysis of detailed information about the Capstone Course learning goals, the project development process, and previous research on information literacy frameworks.

Research questions: The main research questions addressed in this study are:

- What are the connections, similarities and intersections across frameworks in relation to the formulation and development of Capstone Projects in Engineering Education?
- What kind of frameworks and student competencies are involved when formulating and developing Capstone Projects in Engineering Education?

Case selection: The unit of analysis is a Capstone Course section including a group of students participating in Capstone Projects and supervised by a Faculty member at the College of Engineering from the host university, in Fall 2024 and extending through Spring 2025. A theoretical construct sampling strategy [26] guided the selection process, in which the topic of interest is defined well before the researcher goes to the field. Only one course section was selected for this study; it provided comprehensive documentation of the process with which students formulate and develop multidisciplinary projects as part of the course assessment and learning goals.

IRB approval: This study is part of a qualitative research project that received an exempt determination from the host university IRB (Study Number 2024E0519, Qualifying Exempt Category: #2b). The perspectives of Faculty and the experiences of students developing Capstone Projects will be addressed in different studies which are currently work in progress.

Data gathering: The study's data gathering process included a review of the literature on information literacy frameworks, theories and models, with a particular interest in the ACRL Framework [8], Metaliteracy [9], Maker Literacies [10], and case studies addressing the connections, similarities and intersections across frameworks [27]. Once that access was granted to the course syllabus and online course space, it was considered to identify:

- Overall course goals and student learning goals
- Capstone Project timeline, phases, milestones and deliverables
- Capstone Project management model, tools and strategies.

Data analysis: A deductive analysis protocol was conducted by manually mapping the frames across the Project Management Model identified for the Capstone Course [25]. Already existing research results were extremely useful in guiding the analysis in this study: Appendix A shows the convergence of ACRL frames and dispositions and Metaliterate Learner Characteristics, conducted by Jacobson, Mackey and O'Brien [9] and adapted for this study; Appendix B shows the Makers Literacy competencies and subcompetencies as suggested by the University of Texas at Arlington Library team, which were drafted in collaboration with other university partners to explore best practices that incorporate cross-disciplinary, transferable, maker-based competencies into the undergraduate curriculum [10].

4. Results

Capstone course general description: The timeline for students to formulate and develop Capstone Projects involves a sequence of two semesters. The course included five students per team, and six projects in one course section - all students are Honors Engineering majors or Honors Business majors, as an effort to formulate and develop Multidisciplinary Capstone Projects, with perspectives from students across majors. As part of the course, students have to analyze the sponsor's current practices on site to identify opportunities for process optimization.

The phases and milestones to assess the level of progress depend on a Value Creation Process which guided students through a product development cycle. Leadership, teamwork, project management, effective communication, lifelong learning skills, advanced group problem-solving, critical thinking skills and the application of knowledge, research and creativity are described as student learning outcomes for the course. The course syllabus also emphasizes the importance for students to access, explore, discover and use information relevant to their Capstone Projects, including constant curiosity, connections across disciplines and opportunities to create value, as described by the principles of the Kern Entrepreneurial Engineering Network initiative [28].

Previous analyses of frames and dispositions: Several studies conducted comparative analyses across frameworks to scaffold learning and assessment within undergraduate writing curriculum [29, 30] and reported overlap of frameworks and vocabulary, together with explicit connections and intersections among frameworks, characterizing both research and writing frames as part of a "braided process" [31]. A comparative analysis of ACRL frames and dispositions with Metaliterate Learner Characteristics was conducted by Jacobson, Mackey and O'Brien to explore similarities across frameworks [9]; it served as a mapping guide for this study, as shown in Appendix A.

Selecting and mapping Maker Literacy competencies and subcompetencies: As suggested by the University of Texas at Arlington Library team that created the Maker Literacies [10], selecting and mapping competencies and subcompetencies to courses and assignments is a highly individualized process. Therefore, their general guidelines informed the mapping process in this study as follows:

- Identify competencies and subcompetencies that best align with course learning goals or project milestones
- Identify competencies and subcompetencies that relate to cognitive activities students will need to engage with in order to successfully complete project milestones
- Consider results, milestones and skills which are observable and measurable artifacts of learning.

Information literate learners across frameworks: Each phase in the Course Roadmap for the Value Creation Process in the course selected for this study was manually aligned by the researcher to at least one of the ACRL dispositions, a Metaliteracy characteristic and a Makers Literacy subcompetence, highlighting connections and similarities across frameworks. The conceptualization of information literate learners as critical evaluators, consumers and creators of information in collaborative and changing information environments in the ACRL Framework [8] aligns with the Metaliteracy view suggested by Jacobson, Mackey and O'Brien [9], and the Makers Literacy competencies and subcompetencies described by the University of Texas at Arlington Library team [10].

These findings create opportunities for collaborations between subject librarians and Faculty supervising Capstone Projects, in terms of the exchange of ideas to identify more specific information services and tools that better support those competencies aligned with each project phase in the course. A more detailed description of the mapping process and its interpretations by the researcher are provided by semester; then, a discussion of the importance of enhancing the students' practice and application of professional skills is also provided.

Value Creation Process - first semester: Appendix C shows that each phase in the Course Roadmap for the Value Creation Process during the first semester aligns with:

- **ACRL frames and dispositions** where:
    - information seeking and creation is an iterative process
    - information seeking and sensemaking is seen as strategic exploration
    - authority is constructed in the context of the goal and scope for a Multidisciplinary Capstone Project while conducting company, industry and market research.
- **Metaliteracy characteristics,** where students are informed, reflective and adaptable learners, identifying opportunities to create value, improvement or optimization for the project sponsor, while assessing design requirements, policy and technical feasibility.
- **Makers Literacy competencies,** including student abilities to identify and articulate a need while exploring ideas, problems and potential solutions, questioning assumptions, brainstorming and investigating how others have approached similar situations.

Value Creation Process – second semester: Appendix D shows that each phase in the Course Roadmap for the Value Creation Process during the second semester aligns with:

- **ACRL frames and dispositions**:
    - Information has value, where students value the skills, time and effort involved in producing knowledge, and respect original ideas of others, protecting intellectual property emerging as a result of the Capstone Course
    - Information creation is a process, where students create business plans, preliminary designs, design specifications, technical reports, prototypes and final presentations, representing different methods of information dissemination to serve different purposes.
    - Scholarship as conversations, where students see themselves as contributors to scholarship rather than only consumers of it
    - Research as inquiry, where students maintain an open mind and a critical stand, while seeking multiple perspectives across disciplines when gathering information related to a Capstone Project.
    - Iterative prototyping is seen as strategic exploration of information, where students exhibit and develop mental flexibility and creativity while persisting and learning from failures, knowing when they have enough information to complete a full iteration
- **Metaliteracy characteristics,** where students are informed, adaptable, productive, collaborative, open and civic-minded learners, developing and testing potential solutions to create value for the project sponsor, while validating the target market and developing meaningful partnerships with the project sponsor.
- **Makers Literacy competencies,** including student abilities to engage in effective teamwork; assess the appropriateness of materials, equipment and tools; research any limitations for specific applications and technical designs; prototype using iterative design principles; gather preliminary prototype feedback from project sponsors, and understand ethical and intellectual property issues emerging during the Capstone Course.

Professional skills – both semesters: Table 4.1 shows those Makers Literacy competencies which are not explicitly described in the Course Roadmap for the Value Creation Process of the course selected for this study. However, they are included in this analysis since the course syllabus emphasizes the importance of enhancing the students' practice and application of

professional skills through authentic real-world experiences, such as Multidisciplinary Capstone Projects, during both semesters.

These results guided the selection of library resources and tools related to the Course Roadmap and those professional skills targeted as learning outcomes in a Multidisciplinary Capstone Course in Engineering Education. As a result, a LibGuide was created for the course, with feedback and approval from the Faculty member that supervises student projects. The relevance and usefulness of the resources included in the LibGuide created for this course will be analyzed and assessed by the end of the Capstone Course, in Spring 2025.

Student Professional Skills as Learning Outcomes	**ACRL Disposition**	**Metaliteracy Characteristic**	**Makers Literacy Subcompetencies**
Develop a Project Management Plan	See themselves as contributors to the information marketplace rather than only consumers of it	Participatory	6a, 6b, 6c, 6d
	See themselves as contributors to scholarship rather than only consumers of it		
	Understand the responsibility that comes with entering the conversation through participatory channels		
Engage in effective teamwork	Recognize they are often entering into an ongoing scholarly conversation and not a finished conversation	Collaborative	7a, 7b, 7c, 7d, 7e, 7f
	Seek out conversations taking place in their research area		
Employ effective knowledge management practices	Understand that different methods of information dissemination with different purposes are available for their use	Productive	8a, 8b, 8c, 8d
	See themselves as contributors to scholarship rather than only consumers of it		
	Value the skills, time, and effort needed to produce knowledge		
Apply knowledge gained into other situations	Recognize they are often entering into an ongoing scholarly conversation and not a finished conversation	Collaborative	9a, 9b, 9c, 9d, 9e
	Seek out conversations taking place in their research area		
	Seek guidance from experts, such as librarians, researchers, and professionals		

Table 4.1: Frameworks aligned with the development of professional skills for both semesters.

5. Conclusions and future research

The role of makerspaces in fostering collaborations between engineering departments and academic libraries, creating opportunities for further exploration of learning styles and typologies of learning has been described as a top trend in 2024 by the ACRL Research Planning and Review Committee [32].

This research is an attempt to extend our insights regarding the information seeking and sensemaking of engineering students by mapping the ACRL information literacy frameworks and engineering design lifecycle methodologies with alternative frameworks, such as

Metaliteracy and Maker Literacy, to understand the nature of student learning experiences as they formulate and develop Capstone Projects.

This study started exploring the connections, similarities and intersections across frameworks related to student competencies involved in the formulation and development of a Multidisciplinary Capstone Project, and by no means is it meant to draw general conclusions, as it is still a work in progress. Its results reflect the researcher's own interpretations of the concepts involved in each framework and the phases described as part of the Course Roadmap included in the course section selected for the study.

The results emerging from this study could guide instructors and librarians to identify specific competencies and professional skills that engineering students develop in relation to each phase of Capstone Projects, informing the selection of relevant library resources and tools which promote meaningful learning experiences across disciplines. Given the multidisciplinary nature of Capstone Projects and the need to solve real-world problems sponsored by industry, engineering Faculty and students must have access to company and market research tools, project management models, effective communication, technical writing and teamwork guidelines; such a diverse information landscape suggests further and closer collaborations and partnerships between subject librarians as well.

This research will extend the framework analysis to include Capstone Course sections representing other engineering disciplines and using other Project Management Models, for example, the DMAIC Model in Integrated Systems Engineering [33], the BioDesign Process in Biomedical Engineering [34] or the Agile Project Management Approach [35] in Electrical and Computing Engineering. Future research related to this study will include Faculty and student perspectives on the nature of successful Capstone Projects, as well.

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Appendix A: ACRL frames and dispositions aligned with Metaliterate Learner characteristics introduced by Jacobson, Mackey and O'Brien [9]

ACRL Frame	ACRL Disposition	Metaliteracy - Characteristic
Information creation as process	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed
Authority is constructed and contextual	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	
Searching as strategic exploration	Seek guidance from experts, such as librarians, researchers, and professionals	
Scholarship as conversation	Recognize they are often entering into an ongoing scholarly conversation and not a finished conversation	Collaborative
Scholarship as conversation	Seek out conversations taking place in their research area	
Information has value	See themselves as contributors to the information marketplace rather than only consumers of it	Participatory
Scholarship as conversation	See themselves as contributors to scholarship rather than only consumers of it	
Scholarship as conversation	Understand the responsibility that comes with entering the conversation through participatory channels	
Authority is constructed and contextual	Are conscious that maintaining these attitudes and actions requires frequent self-evaluation	Reflective
Authority is constructed and contextual	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	
Information has value	Are inclined to examine their own information privilege	
Information has value	Respect the original ideas of others	Civic Minded
Scholarship as conversation	Recognize that systems privilege authorities and that not having a fluency in the language and process of a discipline disempowers their ability to participate and engage	
Authority is constructed and contextual	Question traditional notions of granting authority and recognize the value of diverse ideas and worldviews.	
Information creation as process	Accept the ambiguity surrounding the potential value of information creation expressed in emerging formats or modes	Adaptable
Searching as strategic exploration	Exhibit mental flexibility and creativity	
Searching as strategic exploration	Persist in the face of search challenges, and know when they have enough information to complete the information task	
Research as inquiry	Maintain an open mind and a critical stance	Open
Research as inquiry	Seek multiple perspectives during information gathering and assessment	
Searching as strategic exploration	Recognize the value of browsing and other serendipitous methods of information gathering	
Information creation as process	Understand that different methods of information dissemination with different purposes are available for their use	Productive
Scholarship as conversation	See themselves as contributors to scholarship rather than only consumers of it	
Information has value	Value the skills, time, and effort needed to produce knowledge	

Appendix B: Makers Literacy Competencies and Subcompetencies, as suggested by the University of Texas at Arlington Library team [10]

Competencies	Subcompetencies
1. Identify and articulate a need to create	1a. Recognize unmet needs and inaccessible situations that might be solved by making 1b. Tinker and hack to learn how things are made and how they work 1c. Isolate a specific, manageable issue to focus on 1d. Evaluate the costs and benefits of making and/or upcycling as an alternative to buying or hiring
2. Analyze and explore ideas, questions, problems, and potential solutions	2a. Define an idea, question, and/or problem 2b. Break an idea, question, and/or problem into its constituent parts for closer analysis 2c. Investigate how others have approached similar situations 2d. Question assumptions 2e. Brainstorm a variety of solutions and pursue the most promising
3. Create effectively and safely	3a. Seek training, information, and necessary certifications when planning to work with dangerous equipment and materials 3b. Wear personal protective gear when appropriate 3c. Reinforce safety precautions with others 3d. Accustom self with location-specific emergency procedures, egress and disaster plans 3e. Transfer safety principles covered in training to real-world contexts
4. Assess the availability and appropriateness of tools and materials	4a. Research various equipment and materials to determine limitations and suitability for specific applications 4b. Consider environmental sustainability/impact when making, including upcycling and recycling materials 4c. Determine the most ideal tools, materials, and method(s) of creation (physical, digital, and rhetorical) for the project 4d. Secure access to the necessary tools, materials, and space/facilities 4e. Investigate alternatives when a desired tool or material is not available or is too resource intensive 4f. Fabricate necessary tools, reimagine material choices, develop alternate workflows, and/or revise project scope when tools or materials are not feasible
5. Prototype using iterative design principles	5a. Specify measurable criteria for a successful prototype vs desired finished product 5b. Divide design into individual components to facilitate testing 5c. Take intelligent risks, use trial and error, and learn from failures 5d. Test measurable criteria to determine whether creation meets needs 5e. Gather prototype feedback and input from stakeholders and mentors

	5f. Revise and modify prototype design over multiple iterations
6. Develop a project management plan	6a. Specify actionable and measurable project goals and requirements 6b. Utilize time management and project management tools 6c. Outline project milestones, including sequential action items and anticipating time for multiple prototype iterations 6d. Work effectively within project constraints, be they financial, material, spatial, and/or temporal
7. Engage in effective teamwork	7a. Gauge the costs & benefits of "Doing-it-Yourself" (DIY) or "Doing-it-Together" (DIT) 7b. Recognize opportunities to collaborate with others who provide diverse experiences and perspectives 7c. Recruit team members with diverse skills appropriate for specific project requirements 7d. Join a team where one's skills are sought and valued 7e. Listen and communicate attentively to learn from and with others 7f. Follow through on commitments and contribute to culture of accountability
8. Employ effective knowledge management practices	8a. Restate technical and maker jargon for the layperson 8b. Document steps clearly with sufficient detail for others to follow and replicate workflows 8c. Use version control to manage project outputs and documentation 8d. Preserve project outputs and documentation for long-term access
9. Apply knowledge gained into other situations	9a. Teach skills and share insights with other makers 9b. Recognize and cultivate transferrable skills 9c. Transfer knowledge, skills, and methods of inquiry across disciplines and activities 9d. Familiarize self with skillsets of others 9e. Connect those seeking to learn something with those who have relevant experience
10. Understand ethical and intellectual property issues surrounding making	10a. Scrutinize the ethical implications of making 10b. Demonstrate an understanding of intellectual property rights and protections 10c. Weigh the costs & benefits of seeking intellectual property protections v. making project outputs open and freely available to others 10d. Examine the potential viability of both proprietary and open source systems to adopt/adapt 10e. Respect the intellectual property rights of other makers

Appendix C: Frameworks aligned with a Value Creation Process for the first semester.

Phase in a Value Creation Process	ACRL Disposition	Metaliteracy Characteristic	Makers Literacy Subcompetencies
Identify opportunity	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed	1a
	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview		
Market and customer research	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed	1c, 1d
	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview		
Create preliminary business model	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed	1c, 1d
	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview		
Define the problem	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2a
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Ranking of user needs	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2b
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Assess policy and regulations	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2b
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Assess technical feasibility	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2b
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Create conceptual solutions	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2e
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Determine design requirements	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2e

	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Concept and usability testing	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2d
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	
Analysis of solutions and selection of final concept	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview	Reflective	2e
	Persist in the face of search challenges, and know when they have enough information to complete the information task	Adaptable	

Appendix D: Frameworks aligned with a Value Creation Process for the second semester.

Phase in a Value Creation Process	ACRL Disposition	Metaliteracy Characteristic	Makers Literacy Subcompetencies
Perform technical design	Understand that different methods of information dissemination with different purposes are available for their use	Productive	4a, 4b, 4c,4d, 4e, 4f
	See themselves as contributors to scholarship rather than only consumers of it		
	Value the skills, time, and effort needed to produce knowledge		
Create prototype(s)	Accept the ambiguity surrounding the potential value of information creation expressed in emerging formats or modes	Adaptable	5a, 5b, 5c,5d, 5e, 5f
	Exhibit mental flexibility and creativity		
	Persist in the face of search challenges, and know when they have enough information to complete the information task		
	Maintain an open mind and a critical stance	Open	
	Seek multiple perspectives during information gathering and assessment		
Verify functions	Accept the ambiguity surrounding the potential value of information creation expressed in emerging formats or modes	Adaptable	5d
	Exhibit mental flexibility and creativity		
	Persist in the face of search challenges, and know when they have enough information to complete the information task		
	Maintain an open mind and a critical stance	Open	
	Seek multiple perspectives during information gathering and assessment		
Update business model	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed	1c, 1d
	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview		
Identify supply chains	Understand that different methods of information dissemination with different purposes are available for their use	Productive	4a, 4b, 4c,4d, 4e, 4f
	See themselves as contributors to scholarship rather than only consumers of it		
	Value the skills, time, and effort needed to produce knowledge		
Develop partnerships	Recognize they are often entering into an ongoing scholarly conversation and not a finished conversation	Collaborative	7b, 7c,7d, 7e
	Seek out conversations taking place in their research area		
Communicate economic terms	Recognize they are often entering into an ongoing scholarly conversation and not a finished conversation	Collaborative	7e
	Seek out conversations taking place in their research area		

Determine resources	Understand that different methods of information dissemination with different purposes are available for their use	Productive	4a, 4b, 4c,4d, 4e, 4f
	See themselves as contributors to scholarship rather than only consumers of it		
	Value the skills, time, and effort needed to produce knowledge		
Validate market	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed	1c, 1d
	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview		
Communicate societal benefits	Recognize they are often entering into an ongoing scholarly conversation and not a finished conversation	Collaborative	7e, 9c
	Seek out conversations taking place in their research area		
Finalize Business Model	Are inclined to seek out characteristics of information products that indicate the underlying creation process	Informed	1c, 1d
	Develop awareness of the importance of assessing content with a skeptical stance and with a self-awareness of their own biases and worldview		
Protect Intellectual Property	Respect the original ideas of others	Civic Minded	10a, 10b, 10c, 10d, 10e
	Question traditional notions of granting authority and recognize the value of diverse ideas and worldviews		