BIOFAB EXPLORER

Invent Your Future

A Digital Tool for Career Exploration into Biofabrication

CAST
Until learning has no limits®

In partnership with

armi Advanced Regenerative Manufacturing Institute

Table of Contents

Executive Summary

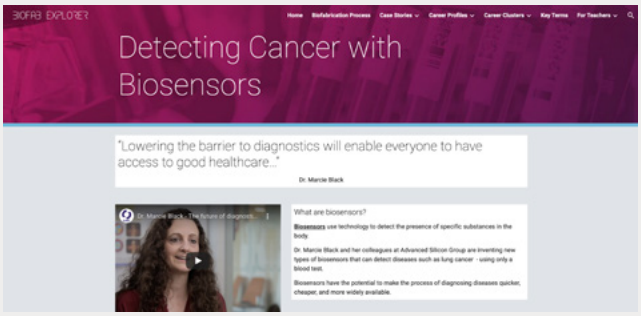
The Biofab Explorer: Invent Your Future career guidance tool can be used by teachers, guidance counselors, and students to build an understanding of biofabrication. CAST designed *Biofab Explorer*, a freely available Google Site, through a contract with the Advanced Regenerative Manufacturing Institute (ARMI)/Biofab USA. The project followed an iterative co-design process that brought together Career and Technical Education (CTE) educators and their students and industry working with ARMI. The project team analyzed gaps in awareness of, and access to, careers in biofabrication, from the educator, student, and industry partner perspective. Knowledge gathered through this co-design process was coupled with evidence-based practices to ensure career guidance serves all learners. Universal Design for Learning (UDL), pioneered at CAST, is an evidence-based framework for designing inclusive learning environments, instructional practices, and flexible educational technologies and materials that give all individuals equal access and support for learning opportunities. *Biofab Explorer* embeds UDL in many ways including by providing learners with several pathways through the content and allowing each individual to build a customized user experience. Information is presented through multiple modalities to provide users with choice. Video, presented in a variety of production styles, puts complex concepts within reach and supports learners to build foundational knowledge. The inherent accessibility of video, with built-in closed-captioning, transcription, and language translation, positions it as an effective vehicle for content delivery.

Biofab Explorer: Invent Your Future is also informed by Social Cognitive Career Theory (SCCT) of how people form career interests, make academic and vocational choices, and succeed or not in education and career pathways (Lent, Brown & Hackett, 1994). Developed with and situated within CTE classrooms, *Biofab Explorer* aligns with the recent passage of "The Strengthening Career and Technical Education for the 21st Century Act" or Perkins V, which, made it clear that the United States believes CTE can uniquely meet the demands of today's economy and is committed to ensuring CTE is accessible to all students. Outlined are four next steps for scaling up *Biofab Explorer* to create career guidance that can attract underrepresented populations to the field of biofabrication. First, pilot the use of *Biofab Explorer* within dual enrollment courses offered in career and technical education high school programs. Second, develop the technology as a software application. Third, leverage Perkins V funding to further develop *Biofab Explorer* within CTE. Fourth, integrate within manufacturing career pathways for low-income youth enrolled in YouthBuild, a national pre-apprenticeship program. Career and Technical Education (CTE) educators and leaders are hungry for approaches like *Biofab Explorer* that facilitate industry links and expose students to real working

environments, meet program requirements, and can be used in real-time in the classroom. Industry too is looking for creative approaches that will connect them to students and fill talent gaps before they arise. Content alone, however, is not the solution. Collaboration between an emerging industry, career-focused educators, and UDL design is the synergy that must be adapted across multiple settings and learning environments to ensure diverse learners can access career pathways into innovative industries of the future.

Project Description

The Biofab Explorer: Invent Your Future career guidance tool provides new ways for teachers, guidance counselors, and students to build an understanding of a complex emerging field - biofabrication. CAST—a non-profit education research and development organization—designed *Biofab Explorer* and it is the primary deliverable for an Education and Workforce Development contract awarded to CAST by ARMI and funded by the Office of the Secretary of Defense. This project, *Uncovering and Engaging a Diverse CTE Student Pipeline for Biofabrication*, focused on co-designing with career and technical education (CTE) high school students and educators in New Hampshire, the Advanced Regenerative Manufacturing Institute (ARMI)/Biofab USA, and ARMI industry members. The collaborative co-design process allowed CAST and ARMI to analyze gaps in awareness of, and access to, careers in biofabrication, from the educator, student, and industry partner perspective and respond with this career guidance tool.



Career Guidance in Biofabrication

Effective career guidance is a complex cycle that includes exposing someone to available careers, helping them discover what they are interested in, providing them with the capacity to document industry-aligned skills and knowledge, and helping them achieve an education/career milestone (Salisbury & Kraft, 2020). Unfortunately, most career guidance at the secondary and post-secondary level happens outside of the classroom in small doses with counselors who are not regularly evaluating a student's skills or surfacing their interests; the average school to guidance counsewlor ratio in high school is 491:1 and that rises to 1,800:1 in college (Ibid). At the secondary level, career development professionals and teachers often lack an understanding of the many career pathways into STEM fields and do not have the means to help students explore these career pathways or develop industry-relevant skills and competencies that put students on these career pathways (Byars-Winston, 2014; Carter et al, 2010). Even in CTE programs where educators are more familiar with career development pedagogy, exposure to a broad range of careers is lacking. Other challenges are that emerging fields such as biofabrication, offer fewer work-based learning opportunities and/or career-related educational opportunities for students to develop their foundational knowledge. And, educational pathways, linking emerging fields with post-secondary options have not been sufficiently mapped, leaving students and educators unaware of the educational steps needed to position themselves for a career in these fields.

Educational software can deliver a customized career guidance experience to schools and other educational settings and can operate across programs and ages, thereby creating an avenue for broadening who is engaged in STEM career exploration as well as how. However, educational software and career guidance content should be co-designed with the target population(s) that will use them and should use evidence-based approaches to learning and teaching that effectively support the learning of a broad range of learners.

Creating Access to Career Guidance for All

Universal Design for Learning (UDL) (Meyer & Rose, 1998; Rose & Meyer, 2002; Rose, Meyer, Strangman & Rappolt, 2002), pioneered at CAST, is an evidence-based framework for designing inclusive learning environments, instructional practices, and flexible educational technologies and materials that give all individuals equal access and support for learning opportunities. Built upon the "universal design" movement in architecture and product development that have made spaces and information more accessible to individuals with disabilities (Mace et al, 1997), UDL research and practice focuses on instructional innovations and interventions that address learner variability (Meyer, Rose & Gordon, 2014). UDL is predicated on three core principles: 1) multiple ways to engage students in learning; 2) multiple ways to present content, and 3) multiple ways for students to demonstrate what they are learning (Meyer & Rose, 1998, Rose & Meyer, 2002; Rose, Meyer, Strangman & Rappolt, 2002; Rose, Meyer & Hitchcock, 2005). In practice, the digital tools developed by CAST embed UDL principles at the outset and employ an accessibility-first approach to product design.

Biofab Explorer embeds UDL in many ways including by providing learners with several pathways through the content, allowing each individual to build a customized user experience. Information is presented through multiple modalities to provide users with choice. The prevalence of multimedia throughout the application, with a particular emphasis on video presented in a variety of production styles, puts complex concepts within reach and supports learners to build foundational knowledge. The inherent accessibility of video, with built-in closed-captioning, transcription, and language translation, positions it as an effective vehicle for content delivery in this format.

UDL is specifically referenced in all federal legislation that governs education (including the Higher Education Opportunity Act, the Every Student Succeeds Act, and most recently the Strengthening Career and Technical Education for the 21st Century Act (Perkins V)). Federal legislation stipulates that school districts, States, and higher education institutions can spend federal dollars on training educators in UDL, procuring universally designed technology, and/or creating universally designed assessments (see: UDL in Public Policy).

In addition to employing inclusive design strategies such as UDL, career guidance opportunities should be informed by career theories that emphasize both person-level and contextual variables, including system-level barriers to pursuing careers. *Biofab Explorer: Invent Your Future* is informed by Social Cognitive Career Theory (SCCT) of how people form career interests, make academic and vocational choices, and succeed or

not in education and career pathways (Lent, Brown & Hackett, 1994). There is a substantial body of evidence that shows SCCT is a useful theory for explaining educational and career interest, choice-making, and performance and is culturally relevant (Lent et al., 2008). SCCT, for example, has been used to predict interest and outcome expectations in engineering careers for underrepresented minorities (Dika, 2016), as well as to design interventions for minorities with disabilities to support career interest and goal persistence in STEM fields (Dutta et al., 2015). In SCCT, academic and career interests are derived from self-efficacy beliefs and outcome expectations. Self-efficacy refers to the beliefs people hold about their ability to complete a given task (Bandura, 1986). Efficacy expectations develop through performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal. Diverse models are better at improving self-efficacy because they illustrate that there is more than one pathway to a goal (Bandura, 1977; Ford, 1992). Finally, outcome expectations are developed through experiences and the perceived results of those experiences (e.g., if I apply myself in my math class, I am likely to get a good grade).

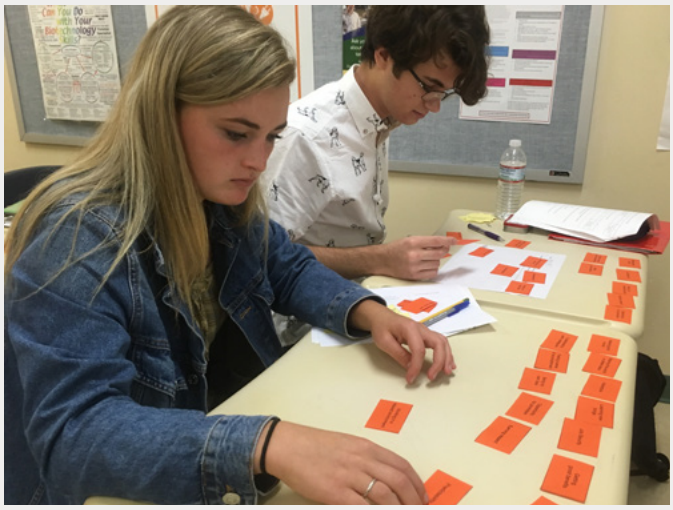
A Focus on Career and Technical Education

Career and Technical Education (CTE) classrooms and programs offer an ideal publicly funded, educational structure through which students can be introduced to, and develop skills in, emerging fields. Designed to purposefully link students to work-based learning (WBL) opportunities and post-secondary credentials, more than 8 million secondary students and 4 million post-secondary students are already participating in innovative CTE programs across the United States (PCRN, 2020). In these classrooms, young women are learning to fly drones, English Learners are becoming certified electrical apprentices, and young men and women are learning how to extract the DNA from strawberries. Whether students go directly into the workforce or choose to attend college, participation in CTE increases the likelihood that students will graduate from high school, have increased earnings, and have higher rates of full-time employment after high school (US Department of Education, 2019).

Plus, the recent unanimous bipartisan passage of "The Strengthening Career and Technical Education for the 21st Century Act" or Perkins V, made it clear that the United States believes CTE can uniquely meet the demands of today's economy and is committed to ensuring CTE is accessible to all students. Not only did Perkins V significantly increase spending on CTE programs and initiatives, but it focused on funding on at-risk "special populations," such as homeless youth, English learners, and students with disabilities. Today, states and school districts are required to spend funds on recruiting, retaining, and supporting students that have traditionally experienced significant barriers. For example, school districts can use their Perkins funds to eliminate out-of-pocket expenses for special populations including the cost of dual enrollment programs, childcare, and/or transportation. Perkins V also includes new accountability provisions that require states and school districts to "continuously make meaningful progress toward improving the performance" of all CTE students, including racial and ethnic subgroups and special populations - such as female students in traditionally male-dominated programs, like automotive technology. During reporting, states must identify disparities without gaps in performance levels between special populations, as well as racial and ethnic subgroups, and must create quantifiable descriptions of progress being made to address these gaps.

Inclusive Career and Technical Education (CTE) classrooms provide a rich venue for career guidance and for Social Cognitive Career Theory (SCCT) to play out. First, CTE purposefully supports students' development of self-efficacy beliefs concerning possible careers. In CTE classrooms, students experience industry-relevant skills in the context of a diverse group of other learners; engage with CTE teachers all of whom have spent time working in the field; utilize industry-specific equipment, tools, and practices; and are exposed to career development skills both in the classroom and through work-based learning (WBL) placements.

The Co-Design Process and Findings



CAST utilized an iterative co-design process to guide the development of *Biofab Explorer*. This unique approach focused on identifying goals, needs, and motivations that could inform *Biofab Explorer's* design and development; to increase relevance and motivate users to engage with the tool by exploring careers available in the biofabrication industry. The CAST co-design process focuses on designing with users during every stage of discovery and development. This strategy ensures users' expertise is leveraged and provides better insight into their authentic needs and experiences. Through this process, CAST produced several prototypes, ultimately developing the current version of the *Biofab Explorer* tool. Content in the prototype includes a series of videos profiling diverse career paths into biofabrication; case stories of individuals positively impacted by biofabrication technology; and activities that teachers, guidance counselors, or students working independently can use to explore career pathways in biofabrication.

As the final component of the co-design process, CAST is releasing the tool as a 'proof of concept.' CAST is releasing the tool to high schools across NH and MA and soliciting feedback. CAST is also sharing the Google Site with higher education and industry partners such as the National Science Foundation's Advanced Technological Education program (e.g., InnovATEBio; AccessATE) and YouthBuild USA, a national pre-apprenticeship program for low-income young people. Since *Biofab Explorer* is a Google Site — available as an open educational resource (OER) — the reach of the tool is significant and responses could therefore include educators/students from across the country. As an Open Educational Resource, videos and other content on the site can be repurposed, reused, and recycled by all educators. To further ensure the materials and resources on *Biofab Explorer* are utilized, CAST hosted a webinar, where educators from across New England were exposed to the tool and taught how to utilize the modules and accompanying Teacher Guide. The webinar included CTE educators, as well as guidance counselors, Extended Learning Opportunity (ELO) coordinators, administrators, and the head of the science department from Brockton, MA. The site was well received and educators shared plans to incorporate *Biofab Explorer* content into their curricula in the 2020-2021 school year. The webinar is recorded and available on CAST's website. CAST also produced a short video, chronicling the process of designing *Biofab Explorer* from the perspective of the research and design team and ARMI's Director of Education and Workforce Development, Dr. Mary Stewart. This **video** can be used to further market the site and increase exposure/dissemination of the materials.

Co-design learning summary

What follows is a summary of the co-design process findings by the stakeholder group. Appendix A provides additional detail on interviews as well as site visits and stakeholders involved.

CTE students

CAST created a set of co-design activities to understand how to best design a tool from the perspective of the end-users - students. Specifically, the co-design process was framed to better understand students' familiarity with STEM, their preferences around learning about new careers, and how students prioritize career attributes. Through small group interactions, interviews, surveys, and observations, CAST found that students were uniformly familiar with and interested in, STEM careers in general. Since all of the initial co-design cohorts came from biotechnology programs, analysis showing that CTE students had a solid understanding of the biotechnology, biomedical engineering, and biofabrication fields was expected.

The co-design process revealed that in the arena of career exploration, students prefer to watch videos, view job and internship listings, and read articles/listen to podcasts about careers. Students further identified that they were most interested in learning pragmatic information related to career preparation. For example, students wanted to know educational requirements for acceptance into STEM-based post-secondary programs, daily career-based tasks, and expected salary for given career paths. CTE students also prioritized career attributes centered on their values. A majority of students wanted to connect with "patients'' and understand how a career in biotechnology would create a pathway for them to help others. Students wanted to "make the world a better place." Further analysis revealed that students were motivated to pursue a career if it provided them feelings of accomplishment and if they were able to learn about new or innovative technology related to the biofabrication career field. The least important career attributes identified by CTE students included staying close to home, predictability, and being their own boss.

CTE educators

The first prototype was user-tested with CTE educators in biofabrication programs in large diverse districts in NH. The goal of this initial meeting was to improve the features and functionality of the tool. After the first round of feedback, additional prototypes were tested with CTE educators in urban and rural engineering, manufacturing, and computer science programs. Based on feedback from these co-design meetings, the tool was designed to align with CTE career clusters; a Teacher Resource page was developed; and activities in the Teacher Resource were designed to explicitly connect a variety of CTE programs — such as manufacturing and engineering — with biofabrication careers and aligned to CTE competencies in these programs.

Industry members

At the outset of this project, CAST partnered with ten ARMY members, representing subject matter experts from a cross-section of the biofabrication industry. Utilizing a combination of co-design strategies including small group interviews, one-on-one conversations, and surveys, the needs, and goals of these stakeholders were identified. CAST was specifically interested in understanding what skills and knowledge industry partners identified as priorities for future employees. For example, as the biofabrication industry begins manufacturing tissues at scale, STEM and manufacturing technicians will be in high demand. For this reason industry members surfaced technical skills related to maintenance of equipment and the ability to problem solve as areas of focus. To convey the industry perspective to end-users, *Biofab Explorer* includes background information about biofabrication, STEM technician career profiles, inspirational case stories, and information on the pathways individual employees took along their own personal route to a career in biofabrication. *Biofab Explorer* also links easy to access and digestible facts around salary, job requirements, and projected growth with these interviews and industry profiles.

Biofab Explorer & UDL

Universal Design for Learning underpins all of the design decisions in Biofab Explorer. The three UDL principles - multiple means of engagement, multiple means of action and expression, and multiple means of representation - are made practical in learning environments through the UDL Guidelines. The UDL Guidelines are a set of three framing principles and 9 broad categories with multiple checkpoints that can be used as needed to inform the design of learning environments. These UDL Guidelines, authored by CAST are based on over 800 peer-reviewed articles of best practices in the learning sciences including neuroscience and research into teaching and learning. Research on each of these guidelines is continually conducted by CAST and others. Below are examples of how the guidelines and checkpoints are featured in *Biofab Explorer* to support all learners to engage with this career guidance tool.

Relevance, value, and authenticity

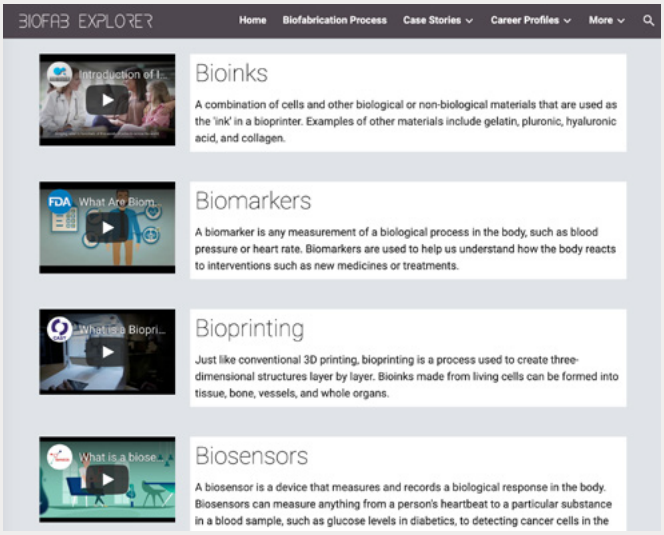
UDL Engagement Principle, Guideline 7 Recruiting Interest, Checkpoint 7.2 Relevance, value, and authenticity

It is well documented that the United States is experiencing a full-blown (STEM) "workforce crisis" (Institute Skills Gap and Future of Work Study, 2018). In fact, "The National Association of Manufacturers (NAM) 2019 1st Quarter Manufacturers' Outlook Survey found that 71.3% of the U.S. manufacturers surveyed cited the inability to attract and retain skilled workers as their top challenge." Locally, New Hampshire and Massachusetts are experiencing this phenomenon first-hand, as they work to position the region to become a hub for biofabrication internationally. ARMI's Roadmap for BiofabUSA Education and Workforce Development plan clearly connects the continued growth of the industry in the region with a need for more high-skilled STEM technicians. Across the country and region, individuals are needed to work in multidisciplinary teams in a variety of technician jobs including cell culture technicians, biologists, automation experts, mechatronics technicians, and others (ARMI, 2018).

The problem, however, is not a lack of ample talent in the region, the problem is an unequal distribution of opportunity to develop this talent. *Biofab Explorer* addresses this inequity by leveraging UDL to bring the biofabrication industry to life in relevant and accessible ways. Through guided activities and video interviews with industry professionals, students have the opportunity to authentically engage with current career data from the Department of Labor in ways that are valuable and meaningful.

Embedded in the *Biofab Explorer* activities are NH CTE competencies connected to manufacturing, biotechnology, engineering, and career development. By aligning activities with state-wide requirements, *Biofab Explorer* becomes a relevant resource for both students and educators. Since the activities and experiences can be tied directly to course completion and credits. Students and educators can access these activities in two primary ways: 1) through a Biofabrication Career Exploration Extended Learning Opportunity (ELO), designed collaboratively with the NH ELO Network and 2) through CAST designed teacher-directed activities. The ELO was designed to connect students with the field of biofabrication, whether they have access to CTE programming or not. Additionally, the ELO can also be used in traditional science classrooms outside of CTE, to enrich students' understanding of career pathways in the emerging STEMfield of biofabrication. The teacher-directed activities were created to add value to the resources by ensuring all educators - working in a variety of classrooms and with varying degrees of experiences and knowledge about biofabrication - could leverage the tool easily and effectively. Both of these activities are found in the teacher resource section of the tool.

Educators can use the resources in the tool to address the CTE requirements for work-based learning (WBL) as well. Through industry interviews and activities found in the Teacher Resource section, *Biofab Explorer* introduces students to the world of work in simulated ways and authentic ways. Since it is notoriously challenging to introduce all students to WBL opportunities in emerging fields like biofabrication, this feature alone significantly increases the value of Biofab Explorer for educators. Indeed, the connection to WBL increases potential use and scalability since 28 states specifically mention a focus on WBL in their current Strengthening Career and Technical Education for the 21st Century Act (Perkins V) plans (B. Robinson, personal communication, September 29, 2020, Advance CTE). For emerging industries like biofabrication, partnering with CTE programs and educators exposes students to the field in relevant ways, leveraging the apprenticeship model, and building more direct career pathways. By developing Biofab Explorer with a focus on increasing relevance, value, and authenticity for students and educators in CTE programs, *Biofab Explorer* becomes a promising tool to meet the looming shortage of STEM skilled technical workers - an anticipated 3.5 million by 2025 in manufacturing alone (Institute Skills Gap and Future of Work Study, 2018).



Building background knowledge

UDL Representation Principle, Guideline 3 Provide Options for Comprehension, Checkpoint 3.1 Activate or Supply Background Knowledge

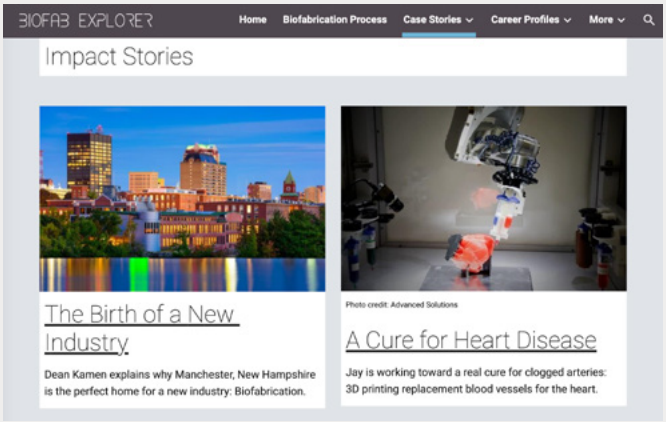
The initial goal of *Biofab Explorer* is to build awareness of the biofabrication industry for first-time users. When a learner visits the website, they are provided with an introduction that breaks down the technical, industry-specific concepts through age-appropriate language and multimedia explainers - demystifying the complexity of biofabrication and inviting every learner in, regardless of their prior knowledge or exposure to the topic.

The specialized terminology associated with biofabrication's processes presents a learning opportunity rather than a barrier to understanding due to the video glossary of key terms hyperlinked throughout the content, offering users just-in-time support.

Individual Choice and Autonomy

UDL Engagement Principle, Guideline 7 Recruiting Interest, Checkpoint 7.1 Optimize Individual Choice and Autonomy

Co-design sessions with students yielded a clear preference for choice when engaging with biofabrication content. When learning about biofabrication's potential, students were evenly split between favoring stories that explored individual patient experiences and those that uncovered the prospective impact on a larger scale. In response to these findings, we developed case stories in two formats: patient stories and impact stories. When reviewing the cases, students can select an entry



point into the material that resonates with their interests and considers their values. Rather than a one-size-fits-all approach to content development that may appeal greatly to some users and fall flat with others, incorporating variety increases engagement and 'stickiness' among users.

Optimizing Access

UDL Action & Expression Principle, Guideline 4 Physical Action, Checkpoint 4.1. Vary the Methods for Response and Navigation

By providing students and CTE educators student-centered technology that can be utilized in remote settings to develop critical skills and knowledge in emerging STEM fields, *Biofab Explorer* addresses many of the challenges and discrepancies that have surfaced following the COVID-19 pandemic. For example, in virtual learning environments, CTE educators and students lose access to lab spaces, internships, and work-study programs, all of which dramatically impact preparation for success in the workforce. *Biofab Explorer* offers contextualized and engaging content with personalized points of entry depending on the need of the student or the educator. For example, biotechnology educators may encourage students to learn about the field of biofabrication by watching and engaging with the patient stories, while a manufacturing teacher may introduce biofabrication using the career profile of a STEM technician who focuses on keeping the 3D printers running.

According to a 2020 review of effective online teaching through COVID-19, researchers found that materials and technology must be "accurate in content, *accessible* to students and adequate to their level of *autonomy*" (Rapanta, et al., 2020). By leveraging a UDL-based framework, *Biofab Explorer* exceeds these recommendations by additionally supporting personalization.

Use Multiple Media for Communication

UDL Action and Expression Principle, Guideline 5 Provide Options for Expression and Communication, Checkpoint 5.1. Use multiple media for communication (5.1)

Creating a digital learning tool furnished the affordance of seamlessly integrating content in multiple formats. Our industry partners generously permitted us to capture interviews and 'b-roll' footage of their offices, labs, and workshops. This allowed us to present students with real-world viewpoints into the careers and companies profiled - showcasing authentic representations of the industry through video. This fulfilled students' desire to understand the tasks and activities that a particular career entails on a daily basis.

In addition to the video CAST produced with ARMI partners, a variety of supplemental videos were embedded in the *Biofab Explorer* resources. These videos range in feel and style, in an endeavor to appeal to the widest audience possible. While each video clip can stand alone, a textual narrative provides a throughline for the videos, giving users the option to watch videos, read/listen to the text, or both.

Build Fluencies with Graduated Levels of Support

UDL Action and Expression Principle, Guideline 5 Provide Options for Expression and Communication, Checkpoint 5.3.Build fluencies with graduated levels of support for practice and performance (5.3)

To ensure that all educators and students, across a variety of abilities and programs, can successfully leverage the resources in *Biofab Explorer*, CAST included activities in the Teacher Guide that are leveled and supported. The levels create a scaffold for educators and students guiding them to appropriate activities based on background and need. And, each of the activities includes multiple ways teachers can deploy the content, as well as multiple ways students can demonstrate knowledge acquisition. For example, students might be asked to analyze careers found in the field of biofabrication and make decisions about their career

trajectory. To support completion of this assignment and guide demonstration of understanding, this activity includes a template for collecting career data, links to career information and samples of information found, as well as models of individuals currently working in the field (through videos linked in *Biofab Explorer*). It is suggested that the activity culminates with the students demonstrating their findings. However, they can select how they want to demonstrate knowledge by creating a presentation they will share publicly, writing a paper on their findings, or even create a video of themselves complete with linked media or photos from outside sources. By supporting the activities this way *Biofab Explorer* embedded the UDL approach within the tool itself. This promotes independence and autonomy for students and guides educators in designing learning in new ways - which over the long-term facilitates success for all learners and generally increases students' perseverance and problem-solving ability.

Continuing the Work

CAST and ARMI envision and have begun to advance the next stages of this effort in four ways outlined below. Each of these approaches serves as a means to attract underrepresented populations into biofabrication and address labor force needs such as the need for STEM technicians in scaling up regenerative manufacturing. These approaches are not mutually exclusive and may require different funding sources and partners to be fully realized. Discussions with ARMI, Office of the Secretary of Defense, other Federal and State partners and ARMI members on each of these options would be welcome and would inform the viability and utility of each option in relation to ARMI's and Manufacturing USA's goals. Dr. Mary Stewart and CAST have discussed, and in some instances, already partnered on these various ways forward.

1. Pilot use of *Biofab Explorer* within Dual Enrollment Courses

CAST, ARMI, CTE High schools, and community college partners in New Hampshire are seeking follow-on funding through the National Science Foundation's Advanced Technological Education program with a grant proposal submitted in October 2020. The proposal is to expand *Biofab Explorer* by creating a series of simulated work-based learning scenarios and testing *Biofab Explorer* in dual enrollment CTE courses in manufacturing, engineering, and biotechnology. Students will use CAST's personalized and portable e-portfolio already in use within CTE Centers in Massachusetts (CTEFolio) to document industry-relevant skills aligned to CTE competencies. This approach, which sets career guidance both inside and outside the classroom, aligns with the recommendations in the National Network for Manufacturing Innovation Program Strategic Plan (2016) – to create an entire domestic innovation ecosystem rather than have innovation isolated within the research community. By co-designing a prototype with young people and their teachers and testing this out in dual enrollment settings, this project would effectively build understanding and ownership of career opportunities in an emerging and complex industry. Talent and opportunity can align when the early end of the talent pipeline is actively recruited to the emerging industry, while students are making choices about their education and career pathways. Figure 1 shows a theory of change for how *Biofab Explorer* in conjunction with work-based learning opportunities within a dual enrollment course would support career guidance and put eligible students on career pathways in biofabrication.

Figure 1. Theory of Change for Biofabrication Career Guidance within Dual Enrolment

Dual enrollment has been identified as an impactful and cost-effective strategy to affordably "jump-start" students' college and career pathways, since it increases students' likelihood of matriculation into postsecondary programs particularly for low-income and CTE students (Zinth, 2018). In NH, dual enrollment or Running Start (RS), is a concurrent enrollment opportunity, allowing students to earn college credit while simultaneously completing their requirements for high school at a fraction of the cost. Unfortunately, RS opportunities are not equally distributed across courses or effectively leveraged for STEM technician career development in NH. In 2019, for instance, despite 100 percent of high schools in NH offering courses with opportunities to earn RS credits, and roughly 11,477 credits earned by secondary students, the most popular courses were taken to meet prerequisite requirements for four-year colleges, and not aligned with STEM technician programs (G. Polish, personal communication, September 25, 2020, NH Department of Education). One significant problem is that CTE programs in the region are not leading students into two-year STEM technician programs. In NH there is only one community college, Great Bay Community College (GBCC), offering a two-year program in biotechnology. Of the 91 secondary students across the state that earned dual enrollment credit in biotechnology (the majority of these through CTE), zero enrolled in the community college biotechnology program. Manchester Community College (MCC) awards dual enrollment credits for manufacturing and engineering across NH (again mostly from CTE programs). Although Manchester Community College has started to work on this challenge through a National Science Foundation ATE grant under Dr. Dan Larochelle (more than doubling the number of students earning RS credit in manufacturing and engineering within one year) there are still no significant numbers of students enrolling in mechatronics, manufacturing or engineering technology programs at MCC.

2. Develop Technology as a Software Application

Biofab Explorer evolved from its initial scope as a planned prototype with no backend technology requirements to its current iteration as a freely-available website. In response to the COVID-19 pandemic and the increased need for online content suitable for remote learning environments, CAST migrated Biofab Explorer into an accessible online format so educators and learners could make use of it immediately. Built on the Google Sites platform, the existing website provided a way to share the prototype with users and test the proof of concept with limited additional functionality, such as an embedded YouTube video player. While Google Sites provided a practical option for rapid dissemination of the content, it does not provide enough flexibility within the interface for an ideal user experience.

To realize the potential of Biofab Explorer and increase the accessibility of the content for the broadest range of users, CAST envisions building *Biofab Explorer* within our **Figuration** front-end development framework to maximize the usability of the technology. Developing *Biofab Explorer* as a dynamic web application would allow for increased user customization and control, resulting in a more personalized learning experience. In the next iteration of this tool, CAST foresees learners building individual profiles to save their user preferences. The inclusion of a tagging structure and a recommendation engine within the content database would provide additional navigational support through the content and allow users to discover curated opportunities based on their choices. Features such as geotagging could be incorporated to allow users to find local opportunities such as jobs or internships aligned with their interests.

3. Leverage Perkins V Funds to Further Develop *Biofab Explorer* within CTE

Link Biofab Explorer to STEM learning at the Middle School Level

CAST recommends developing resources and activities in Biofab Explorer that can be used at the middle school level, since this is a statistically beneficial time to begin career exploration, especially for female students (Bottia, Stearns, Mickelson, & Moller, 2017). While robust career exploration has not traditionally been supported at the middle school level, national momentum is growing to increase career exploration opportunities for middle school students through CTE (Godbey & Gordon, 2019); in part, because participation in CTE increases the likelihood students will graduate from high school and complete college (US Department of Education, 2019; Dewitt, 2018). And, because CTE funding has recently increased allowable spending to support middle school programming (Perkins V). Bringing CTE connections to middle schools through Biofab Explorer could potentially increase the number of non-traditional (female) students selecting STEM pathways at the secondary and post-secondary levels. Since, even today, women remain disproportionately underrepresented in STEM careers, making up only a small proportion of good jobs in advanced manufacturing (7%), transportation (9%), and construction (3%) (Institute for Women's Policy Research, 2016).

Facilitate Hands-on Activities and Real-Time Links to Industry Through Biofab Explorer

Many CTE Centers, especially those located in rural geographically isolated areas such as NH's North Country, cannot afford the equipment or technology needed to outfit full STEM labs. However, they can afford to invest in specific pieces of equipment, like pipettes, and/or a tool such as Biofab Explorer. As part of our co-design efforts, CAST met with CTE directors in rural centers. Directors from these centers expressed great interest in affordable tools that could be used to promote career exploration, facilitate the development of specific hands-on skills through embedded activities, and connect students to industry professionals. One of the biggest areas of feedback from CTE Directors, was the need for students to more frequently engage with ARMI (or other industry partners). Directors specifically point to the new Perkins V push for work-based learning WBL, which they could leverage to purchase tools if the tools included simulated experiences, like those provided by Biofab Explorer. Biofab Explorer could be designed as a gateway to facilitate connections with ARMI partners – through Zoom-based interviews or short-term internships -- ultimately creating opportunities for students to explore a career in biofabrication through meaningful dialog with current employers.

Utilize Biofab Explorer as a Tool to Increase Educators' Knowledge and Use of UDL

Despite NH's state-wide funded effort to ensure all educators are familiar with and utilizing UDL, high school teachers (specifically those in STEM areas) are not engaging with the NH UDL Cohort at the same rates as other educators. Therefore, CAST suggests that instead of leading with UDL directly, educational leaders, CAST, and ARMI partner together to create strategies that bring UDL to CTE and STEM teachers through the use of Biofab Explorer. Through this free resource, CTE teachers and science/STEM teachers across the state would be introduced to the UDL design principles and affordances. Through engaging professional development targeted to introduce Biofab Explorer to STEM teachers (at the secondary and post-secondary levels), teachers could simultaneously be introduced to UDL-based methodologies, research, and practices. Using the tool as a hook and delivering training on the tool through a UDL lens, a package would be created that culminates in more STEM educators receiving the UDL Level 1 credential (which is already paid for through NH DOE funding). It is important to note that through co-design Biofab Explorer already includes CTE competencies in manufacturing, engineering, and biofabrication, as well as National Science standards through Next Generation Science Standards - making the tool useful across a variety of STEM classrooms.

4. Integrate within Manufacturing Career Pathways for Low-income Youth enrolled in a National Pre-apprenticeship program

YouthBuild is a Department of Labor funded national pre-apprenticeship program managed by local non-profits or community colleges and operating in 46 states. Each year YouthBuild works with 8,000 low-income young adults, primarily 16 to 24-year-old young men of color, to help them obtain their high school degree or equivalency, access training within career pathways, and become leaders in their community. Seventy-four percent of YouthBuild graduates go on to employment and postsecondary education, yet few are exposed to STEM or manufacturing career pathways, and this team's knowledge, none have had exposure to the biofabrication industry while enrolled at YouthBuild. This is an enormous source of untapped talent. For every 10,000 low-income, high school freshmen, only 710 will graduate college and only 30 will eventually earn a bachelor's degree in a STEM field (Kailikole, 2010).

CAST has a multi-year partnership with YouthBuild through a National Science Foundation grant to develop and research a personalized and portable e-portfolio to support STEM career exploration and engagement. Through this existing partnership, it has become abundantly clear that young people at YouthBuild have a great deal of STEM interest, skills, and talent and would be well suited to the field of biofabrication or other areas of advanced manufacturing. CAST is collaborating with YouthBuild programs across the country to support the use of this e-portfolio tool (STEMFolio) and is discussing the use of the e-portfolio in conjunction with Biofab Explorer within YouthBuild Charter School of California and YouthBuild Preparatory Academy in Rhode Island. These YouthBuild programs would agree to use Biofab Explorer modules and the teacher guide in conjunction with STEMFolio to explore career pathways into biofabrication, determine how their skills, values, and interests might align with these career pathways, and document industry-relevant skills using STEMFolio. Programs would also participate in focus groups with CAST to align *Biofab Explorer* with that program's needs and circumstances and to understand the efficacy of this approach to career guidance and STEM skill documentation. Findings from this project would inform how to better support young people in YouthBuild in career exploration in emerging STEM industries as well as create a tighter linkage between YouthBuild USA and the Manufacturing USA Institutes. This effort aligns with YouthBuild's current priority to create a manufacturing career pathway.

Final Thoughts

In addition to the creation of a functional, free, open educational resource (OER), designed to support equitable access and exposure to the biofabrication industry through relevant videos and authentic career guidance, with activities linked to state and national standards, the *Biofab Explorer* project yielded two critical revelations. First, Universal Design for Learning (UDL) is an essential component of career guidance, and second, career guidance is a necessary component of a classroom scope and sequence. Resources on the biofabrication industry and other emerging industries belong not only where students already have a sense of biofabrication; they are needed throughout the educational landscape and should be embedded in engineering, manufacturing, and even in AP science programs. Career and Technical Education (CTE) educators and leaders are hungry for approaches like *Biofab Explorer* that facilitate industry links and expose students to real working environments, meet program requirements, and can be used in real-time in the classroom. Industry too is looking for creative approaches that will connect them to students and fill talent gaps before they arise. But, content alone is not the answer. These connections and resources need to be designed to

meet the needs of educators and students. This is where the UDL framework comes in. Without a focus on providing quality materials, designed to increase access and support student success, educators and industry partners run the risk of exacerbating the problem by creating additional barriers that continue to support a system of exclusion and marginalization for specific populations. Collaboration between an emerging industry, career-focused educators, and UDL design is the synergy that must be adapted across multiple settings and learning environments to ensure diverse learners can access career pathways into innovative industries of the future.

Biofab Explorer was a collaborative effort between CAST, ARMI, ARMI Industry members, and CTE students and educators across NH and beyond. It would not have been a success without this collaboration, especially the leadership of Dr. Mary Stewart at ARMI, ARMI membership support lead Taylor McLeod as well as ARMY leadership, especially Dean Kamen who had the vision for ARMI and has looked far and wide for talent to scale up regenerative manufacturing. The Department of Defense has invested in creative approaches to talent development making this project possible. CAST would like to thank in particular Michael Britt-Crane, Education and Workforce Development Lead for the DoD Manufacturing Technology Program Office, and Gregory Henschel, Senior Policy Analyst at US Department of Education. While many ARMY members contributed their time to this project, Dr. Marcie Black of Advanced Silicon Group, Avi Minocha and Chris Slater of CellLink, Stu Jacobson and Keira McGrath of DEKA, John Getz of Roosterbio, and Jay Hoying of Advanced Solutions Life Sciences played significant and critical roles. Dr. Deborah Audino, Professor of Biotechnology, Biotechnology Program Coordinator, Great Bay Community College, Portsmouth, NH, and Dr. Esmaiel Jabbari, Professor of Chemical and Biomedical Engineering, University of South Carolina, Columbia, SC served as advisors and reviewed the prototype and provided valuable feedback. Other experts gave generously of their time, reviewed the prototype, provided valuable feedback and ideas on how this career guidance tool could best serve the STEM workforce. These experts include Dr. Thomas Tubon Ph.D. CoPI, NSF ATE InnovATES BIO National Center for Biotechnology at Madison College, Russ Read InnovATEBIO Co-PI, Dr. Linea Fletcher InnovATES BIO Principal Investigator and Biotechnology Department Chair, Austin Community College, Rachael Bower, Principal Investigator ATE Central, Dan Larochelle, Advanced Manufacturing Technology Department Chair, Manchester Community College and Dr. Jared Ashcroft, Principal Investigator, Micro-Nano Technology Center (MNT-EC), professor of natural sciences at Pasadena City College in Pasadena, CA. Also, CAST would like to extend a special thank you to all of the educational collaborators who supported this project including Abraham Ewing, Gill Morris, Jen Kiley and Karen Fabianski from the ConVal School District, John Finacciaro, Bob Lalancette, Teressa Rosseti, Francine Brown, and Divya Nagri from the Nashua Technology Center, Karen Machado and Ronald Miller from the Manchester School of Technology, Doug Cullen and Donna Couture from the NH ELO Network, Rob Scott and educators at White Mountains Regional High School, and Shawn Desmond and educators from the Brockton, MA School District. The team at CAST included Alison Driscoll, Cara Wojcik, Amanda Bastoni, Janet Gronneberg, Patricia Ganley, Sam Johnston, Sue Brau, and collaborator James Galdos. Each individual and the organization they represent lent thought and expertise to the development of this tool - in the hope that ultimately it will be used to create STEM-based career pathways that expose all students to this incredibly dynamic, future-oriented emerging industry - that is biofabrication.

References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215.

Bandura, A. (1986). Social foundations of thought and action: a social cognitive theory. Englewood Cliffs, NC: Prentice-Hall.

Bottia, M.C., Stearns, E., Mickelson, R.A., & Moller, S. (2017). Boosting the Numbers of STEM Majors? The Role of High Schools with a STEM Program. *Science Education*, 102(1), 85-107.

B. Robinson, personal communication, September 29, 2020, Advance CTE)

Byars-Winston, A. (2014). Toward a framework for multicultural STEM-focused career interventions. The Career development quarterly, 62(4), 340-357.

Carter, E. W., Trainor, A. A., Cakiroglu, O., Sweden, B., & Owens, L. A. (2010). Availability of and access to career development activities for transition-age youth with disabilities. Career Development for Exceptional Individuals, 33(1), 13-24.

Dika, S., Alvarez, J., Santos, J., & Suárez, O. M. (2016). A social cognitive approach to understanding engineering career interest and expectations among underrepresented students in school-based clubs. Journal of STEM Education: Innovations and Research, 17(1).

Dutta, A., Kang, H. J., Kaya, C., Benton, S. F., Sharp, S. E., Chan, F., da Silva Cardoso, E. & Kundu, M. (2015). Social-Cognitive Career Theory predictors of STEM career interests and goal persistence in minority college students with disabilities: A path analysis. Journal of Vocational Rehabilitation, 43(2), 159-167.

Dewitt, S. (2018). Why middle school? Why now? *Techniques*, 93(3).

Ford, M. E. (1992). Motivating humans: Goals, emotions, and personal agency beliefs. Sage Publications.

G. Polish, personal communication, September 25, 2020, NH Department of Education

Godbey, S., & Gordon, H.R.D. (2019). Career Exploration at the Middle School Level: Barriers and Opportunities. *Middle Grades Review*, 5(2).

"H.R. 4137 — 110th Congress: Higher Education Opportunity Act." www.GovTrack.us. 2007. August 4, 2018

"H.R.2353 - Strengthening Career and Technical Education for the 21st Century Act. August 18, 2018 https://www.congress.gov/bill/115th-congress/house-bill/2353

Institute Skills Gap and Future of Work Study (2018). Deloitte and The Manufacturing Institute. Retrieved August 12, 2020, from MI-Deloitte-skills-gap-Future-of-Workforce-study-2018.pdf.

Institute for Women's Policy Research (2016). Pathways to equity: Narrowing the wage gap by improving women's access to good middle-skill jobs. Retrieved August 12, 2020, from http://womenandgoodjobs.org/wp-content/uploads/2016/03/Middle-skills_layout-FINAL.pdf.

Kailikole, K. 2010. Louis Stokes Institute for Opportunities in STEM Education, Council for Opportunity in Education (COE) Retrieved from NDIA Proceedings Kailikole Presentation

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. Journal of vocational behavior, 45(1), 79-122.

Lent, R. W., Sheu, H. B., Singley, D., Schmidt, J. A., Schmidt, L. C., & Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. Journal of Vocational Behavior, 73(2), 328-335.

Mace, R., Connell, B. R., Jones, M., Mueller, J., Mullick, A., Ostroff, E., ... & Vanderheiden, G. (1997). The principles of universal design. *The Center for Universal Design, North Carolina State University.*

Meyer, A., & Rose, D. (1998). Learning to Read in the Computer Age. In J. Chall (Series Ed.) & J. Onofrey (Ed.), *From Reading Research to Practice*. Cambridge, MA: Brookline Books.

Meyer, A., Rose, D.H., & Gordon, D. (2014). *Universal design for learning: Theory and Practice*. Wakefield, MA: CAST Professional Publishing.

National Science Board (2019). The skilled technical workforce: Crafting America's science & Engineering enterprise. Retrieved August 12, 2020, from **https://www.nsf.gov/nsb/publications/2019/nsb201923.pdf**.

Perkins Collaborative Resource Network (2020). CTE Research Network. Retrieved, August 16, 2020, from **https://cte.ed.gov/initiatives/cte-research-network**.

Rapanta, C., Botturi, L., Goodyear, P. Guardia, L. & Koole, M. (2020). Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity. Postdigit Sci Educ 2, 923–945 (2020). **https://doi.org/10.1007/s42438-020-00155-y**

Roadmap for BiofabUSA Education and Workforce Development 2018-2019. (2018) *ARMI*.

Rose, D.H., and Meyer, A. (2002). *Teaching every student in the digital age: Universal Design for Learning.* Alexandria, VA: Association for Supervision and Curriculum Development.

Rose, D. H., Meyer, A., Strangman, N., Rappolt, G., & Association for Supervision and Curriculum Development. (2002). *Teaching every student in the Digital Age: Universal design for learning*. Alexandria, Va: Association for Supervision and Curriculum Development.

Rose, D. H., Meyer, A., & Hitchcock, C. (2005). *The Universally Designed Classroom: Accessible Curriculum and Digital Technologies.* Cambridge, MA: Harvard Education Press.

Salisbury, A., & Kraft, K. (2020). Unlocking Career Potential: An Analysis of the Career Navigation & Guidance Product Landscape. Entangled Solutions. Retrieved from **https://www.entangled.solutions/wp-content/uploads/2020/04/Entangled-White-Paper-Unlocking-Career-Nav_28Apr20_vFINAL.pdf**

U.S. Department of Education (2019). Science, Technology, Engineering, and Math Including Computer Science. Retrieved August 12, 2020, from **https://www.ed.gov/stem.**

Zinth, J. STEM Dual Enrollment Model Policy Components. (2018). Education Commission of the States. Retrieved September 28, 2020, from **https://www.ecs.org/wp-content/uploads/STEM-Dual-Enrollment-Model-Policy-Components.pdf**.

Appendix A

Date	Location	Total Participants (students / teachers / employees)	Purpose of visit
3/25/2019	Nashua High School North	3 Teachers/ 1 Director of CTE	Overview of school, f2f with Amanda CTE dir, talk with CTW teachers
4/11/2019	Machester School of Technology	3 Teachers, Principal, Assistant Principal	Meet principal and talk to teachers
4/11/2019	Advanced Solutions Life Sciences	3 Scientists	Get to know organization and what they do, potential protagonists
4/11/2019	DEKA Research	3 Scientists	Meet Stu Jacobson and team
4/11/2019	Rockwell Automation	1 Manufacturing/ Salesperson	Meet Wayne Charest and team
5/09/2019	AAdoup		Meet Marcie Black
6/11/2019	Manchester School of Technology	6 Students/ 1 Teacher	Discovery focus group with students
8/12/2019	Advanced Silicon Group Filming	3 Employees	Filmed Interviews
9/23/2019	Nashua Tech Center Focus Group	15 Students/ 1 Teacher	Discovery focus group with students
10/28/2019	Advanced Solutions Life Sciences	3 Staff	Focus group, filmed interviews with industry partners
11/20/2019	DEKA Research	6 DEKA Employees	Focus group and discussion and brainstorming around future content contributions

Appendix A Continued

Date	Location	Total Participants (students / teachers / employees)	Purpose of visit
1/23/2020	Esmaiel Jabbari Call	1 Advisor, 2 Project Personnel	To demo the clickable prototype to our advisor and receive feedback and plan for contributions to content
2/03/2020	Deborah Audino Call	1 Advisor, 4 Project Personnel	Demo clickable prototype, solicit feedback, discuss additional input/ resources
2/06/2020	Advanced Solutions Virtual Focus Group	Jay Hoying and 2 Associaties	To demo the clickable prototype to our advisor and receive feedback and plan for contributions to content
2/07/2020	Rooster Bio Virtual Focus Group	2 from CAST, 3 from Rooster	To demo the clickable prototype to our advisor and receive feedback and plan for contributions to content
2/19/2020	Nashua South Focus Group	4 CTE Classes	To demo the clickable prototype to CTE students
3/09/2020	ConVa Focus Group	3 CTE Teachers, 2 CAST Staff	To perform user testing on clickable prototype, receive feedback on prototype content discuss ideas for teacher guides, challenges