I-Corps™ L Final Report

THE STUDY WAS LED BY ALAN PETERFREUND (SAGEFOX), GARY LICHTENSTEIN (QUALITY EVALUATION DESIGNS) AND REBECCA ZARCH (SAGEFOX), AND FUNDED THROUGH VENTUREWELL UNDER THE LEADERSHIP OF PHIL WEILERSTEIN.

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I. EXECUTIVE SUMMARY

I.I OVERVIEW

This report presents the findings of a two-year longitudinal study of the I-Corps™ L (ICL) program. The study was funded through an EAGER grant to VentureWell, with lead partners SageFox Consulting Group and Quality Evaluation Designs (QED), (NSF # 1551463).

The study was led by Alan Peterfreund[1], Gary Lichtenstein[2], and Rebecca Zarch[3], and funded through VentureWell under the leadership of Phil Weilerstein.

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The objectives of this study were to:

1. Understand and document the outcomes of ICL with respect to sustaining and scaling innovations.
2. Understand and document if and how the participating team members apply what they learned through ICL
3. Identify and define the start-up ecosystem in which ICL innovations scale and sustain.

This work began with the following, overarching questions:

Q1. **What are the outcomes of participation in ICL on the teams' innovations, the team members' personal and professional development?**

Q2. **What are the key features of and pathways within the ecosystem(s) in which ICL team members seek to successfully scale and sustain their STEM education-related innovations?**

Data contributing to the study are from surveys conducted with 63 ICL teams at two time points for PIs and ELs in cohorts 1 & 2 and once for cohort 3, once for all mentors, and over 30 interviews conducted with I-Corps™ L participants, and experts in the field of entrepreneurship. Teaching Team faculty and NSF Program Officers were also interviewed. All data were collected according to New England IRB #15-274.

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I.II Summary Findings

These findings are presented with an appreciation that the variations in the experience and progress of teams are complex. For example,

1. The make-up of the teams in each cohort differed based on the pool of applicants, resulting in variations in innovation maturity and history of funding.
2. Within a team, there were variations in the roles and motivations of the individuals.
3. The experience in the course may have had an effect on teams.
4. The post-course context had a profound impact on how successful a team is in scaling and/or sustaining and/or commercializing their innovations.

We offer three overarching takeaways related to the research questions:

1. *Sustaining* versus *Scaling is an important distinction for ICL participants.* To many PIs we interviewed, sustaining an innovation is not seen as a pre-condition of scaling. Making an innovation self-sustaining would be considered a success by these PIs, if doing so yielded perpetual benefits to individuals and institutions that are comparable to those achieved through three- or five-year grant awards.
2. *Whether teams seek to simply sustain their innovation beyond grant funding or whether they seek to scale broadly, ICL was valued as a stepping stone to success.* Nearly all active teams with customers attributed some to much of their success to ICL. The program changed their thinking about what they do and how they do it, causing many to apply an entrepreneurial mindset to their research.
3. *ICL training is a necessary but insufficient vehicle by which to promote either sustaining or scaling of NSF innovations.* Both in spite of and because of the transformation towards an entrepreneurial mindset, some PIs felt let down by NSF due to lack of ICL follow-up support.

I.III Teams

Most teams were still active at the time they took the first survey (~7-11 months post-training) and three quarters were active at the second administration (~19-24 months post-training).

Teams came to the ICL course with innovations in various stages of development, from a well-tested innovation to one selected for the purposes of participation in the course. The history and amount of pre-I-Corps-L funding appears to be a factor in predicting the subsequent progress of the teams.

As the innovations advanced, most teams stayed in an academic setting, even if they anticipated shifting to a new structure. That said, the most active teams 18-24 months after the course had increased levels of problems associated with being hosted their home institutions. Approximately 8-12 months after ICL, teams were equal in having higher education and K12 markets. By 18-14 months after the course, the active teams were more likely to be in K-12.

The greatest barriers to advancing the innovations were consistently related to lack of financial and human resources. The analysis shows that though most of the PIs were involved over the life of this

study, along with continuous funding, the sustained involvement of the EL made a difference for how successful a team was.

I.IV Individuals

The ICL program had positive impacts on individuals and the participants were favorable about the program. The effects of ICL were seen mostly through participants developing entrepreneurial mindsets and not in a new career path. In general, the participants self-described themselves as inexperienced in business or law, particularly as it relates to commercialization of a business venture. The participants are not looking to move out of their current professions; rather, they turn to ICL looking to sustain and/or scale their innovations.

I.V Mentors

Each team had a mentor that participated in the course, offered guidance, and may have conducted customer discovery interviews. Most mentors were not entrepreneurs and lacked experience in the educational ecosystem, thus, they were not appreciably different than the PIs and ELs in their background in customer discovery, the task for which they were providing primary support. It is possible they had skills and expertise that was untapped given the structure of the ICL course. Mentor experience or job status did not appreciably affect ICL and/or innovation outcomes, even when mentors were entrepreneurs. Despite the variance in the selection, engagement, and maximization of mentor expertise, there is an overall positive attitude towards ICL as a process for moving an innovation forward and as a learning experience on behalf of the mentors.

I.VI Interview Study: Team Motivations, Intentions, Supports, and Obstacles

The interviews conducted with the ICL participants confirm the findings above, highlighting several key themes. First, grant funding has been integral to nearly all innovations that have developed since ICL. Although ICL participants were exhorted during the training to avoid grant support, grants have supported 92% of interview respondents. For many PIs, grant funding provided in-kind support from the institution. Many ICL participants are experienced grant-getters whose skills can sustain their innovations during start-up. After start-up, however, only 30% of interviewees expected to rely on grants.

Second, although ICL participants are encouraged to start companies, the majority will not. Two-thirds of interviewees report that their innovations rely on institutional support during-start-up, and all but one expected to continue to rely on their institution during sustaining and scaling phases. Included in this group are several PIs who have formed companies. When it comes to learning innovations developed by ICL alumni, distinctions between “company” and “not a company” blur. Some companies continue to operate within or in tandem with PIs’ institutions. Some innovations that have not formed into companies operate relatively independently as units within their institution.

Third, ICL alumni often admitted that innovation development was stymied by their lack of business acumen and/or access to those who have it. We see having business support or not as a potentially critical variable in the successful development of learning innovations. Business support was greatly valued when it occurred and often desired when it had not. Nearly all PIs who had access to business expertise also had specific and shared scale plans and intended to grow *moderately* or *a lot*. Some who had business support desired more. Having a scale plan that is detailed and shared seemed a distinguishing factor across the innovations.

Effective customer discovery—the focus of ICL—is only the first step to effectively scaling an innovation, and most alumni lack the expertise or access to necessary expertise to move viable innovations towards commercialization. ICL provides the knowledge and motivation to conduct customer discovery, but many who discover promise in their innovations require further business/operational knowledge and expertise beyond those involved with customer discovery.

I.VII Recommendations for the ICL program

***Beyond Customer Discovery*:** ICL focused almost entirely on customer discovery. While the Business Model Canvas (BMC) was explained, most of the faculty's and teams' effort was focused on identifying and aligning value propositions and customer segments. Success leads most teams to advance their innovation. These teams would benefit from a follow-on program that focused on strategies for sounding the completed BMC, gathering evidence of the BMC viability through sales and/or follow-on grants, and scaling an innovation. An advanced course could also cover navigating opportunities and challenges within the host institution and other common issues that face education innovation development.

Entrepreneurial Lead: The role of the EL appears to be critical to the continued progress of the innovation. Given that most PIs show little inclination to significantly change their career path, it may be more critical encourage teams to have an EL that embraces the potential opportunities that advances in the innovation may offer.

Mentor Model: The ICL model of one mentor per team, typically selected by the project team, may not be the most effective approach. There is no evidence that the mentor model contributed to the development of the innovation or the sustainability and/or scalability of the innovation. Mentors were valued by team members and seen as important, yet there is no correlation between mentor involvement and project success. Given the variation in background and experience, the ICL study team recommends that ICL program develop a set of mentors that can work as advisors across projects. Ideally, these mentors will be available to the project teams for a period of time after the course as they attempt to scale and/or sustain.

Better engagement of the host institutions: Based on these results, conversations between ICL Teams and their host institutions appear to have been very limited. Many of the teams don't match the profile of technical innovations that universities are learning how to support. As such, more dialogue needs to

be encouraged at the time of application and through the ICL process that helps teams understand what support might be available or needed from their host institution and in turn for the host institutions to understand what support is needed by the team.

Create New Funding Opportunities for Education Innovations: NSF can foster innovation in the education ecosystem through a program that parallels SBIR and STTR through an Education Innovation Research program. PIs could use data from customer discovery and subsequent activity to generate new output research related to innovating in the education ecosystem, which is typically characterized by a) having no IP and b) working within an institution (intrepreneurship). Such a program would align with Research Types 3, 4 & 5 of Common Guidelines for Education Research & Development:[4]

- Research Type 3: Design & Development Research
- Research Type 4: Efficacy Research
- Research Type 5: Effectiveness Research

An Education Innovation Research program would constitute scale-up research that would explore the little-known and understood education ecosystem, which could have broad impacts across higher education: *"Efficacy, Effectiveness, and Scale-up Research contributes to evidence of impact, generating reliable estimates of the ability of a fully-developed intervention or strategy to achieve its intended outcomes".*[5]

I.VIII RECOMMENDATIONS FOR FURTHER STUDY

This study provides a rich data set and a strong foundation by which to understand the ICL program as a process for supporting NSF PIs in sustaining, scaling, and/or commercializing a learning innovation.

Originally, the ICL Longitudinal Evaluation Team sought to characterize the ecosystems within which ICL innovations sustain and scale. We learned early on that operationalizing *ecosystem* would involve extensive study of individual innovations that could not be supported by the funding and timeline of the current evaluation. Instead, we shifted our focus to the precursors of ecosystem; that is, the motivations, intentions, supports, and obstacles that shape the innovation and its users, and the administrative structure and environment within which they are situated. The full extent of the ecosystem in which ICL teams are sustaining and/or scaling their innovation is still not well understood. It is so complex and multifaceted, the work required falls outside the bounds of this study. That said, this study does provide the precursor to a study of ecosystem by helping to define the elements that contribute to understanding the environment and contextual factors that influence and are influenced by the larger ecosystem.

Additional topics of particular interest of further study are:

- The differences between innovations seeking to sustain and/or scale when providing an innovation targeted to higher education versus the K-12 environment. This study found those in

[4] Common Guidelines for Education Research & Development, NSF 13-126
[5] Ibid., p. 9

K-12 were more likely to remain active, though it is unclear if it is due to the nature of the innovation, the availability of grant support, features of the ecosystem such as market channels, or other variables.

- The impact of ICL teams seeking to sustain and/or scale on the home institutions, and the institutional context's impact on their ability to sustain and/or scale is still not well understood.
- Further research would be required to discern whether having business support causes teams to develop specific and shared plans for scaling, or whether intending to scale causes PIs to seek business support.
- EL activity is highly correlated with the activity level of each team, but it is difficult to determine the direction of causality; ELs may only stay involved in ICL if the innovation appears to be making progress, but they could also be a significant source of momentum. As mentioned elsewhere in this report, ICL ELs are distinct from the comparable role in the canonical I-Corps™, and further study is required in order to understand the unique role they play on ICL teams.
- Many individual participants indicated that even though their career did not change, the way they accomplish their day-to-day duties has evolved substantially to incorporate the training of ICL and the entrepreneurial mindset it emphasizes. More information on the impact of ICL training outside of the innovations themselves would be useful in evaluating the impact of ICL at a more holistic level.
- Ultimately, this research would benefit by being able to consider a various set of control groups. These could be in terms of the modality of support focused on scaling and sustainability experienced by ICL (based on LeanLaunch Pad). One could also consider the advancement of NSF funded educational innovations to better understand why some scale and/or are sustained while others don't. Finally, a comparison could be conducted focused on the participants to see if their growth in entrepreneurial mindset changes as a consequence of this intervention more or less than others that are offered.

The Research Team is grateful to I-Corps™ L team members, who completed surveys and participated in interviews. We also appreciate the support of NSF Program Officers, in particular Drs. Don Millard, John Krupczak and Karen Crosby for their support of the program and the study. Special thanks to American Association for Engineering Education for their commitment to the program and support in helping the study team interpret findings.

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III. GLOSSARY OF TERMS

1. *ICL:* The abbreviation of I-Corps™ L, a spin-off of the nationally recognized I-Corps™ course designed to foster commercialization of grant-funded projects and the primary subject of this report.
2. *Cohort 1:* The first set of ICL participants[6], who took the course in Jan/Feb 2015. These participants were invited to respond to the Fall 2015 survey as well as the Spring 2017 Survey.
3. *Cohort 2:* The second set of ICL participants, who took the course in July/August 2015. These participants were invited to respond to the Spring 2016 Survey as well as the Spring 2017 survey.
4. *Cohort 3:* The third and final set of ICL participants involved in this report, who took the course in July/August 2016. These participants were invited to respond to the Spring 2017 survey.
5. *Time 1 (T1):* The first survey taken by respondents. For Cohort 1, T1 is the Fall 2015 survey, for Cohort 2 it is the Spring 2016 Survey, and for Cohort 3 it is the Spring 2017 survey.
6. *Time 2 (T2):* The second survey taken by respondents. This corresponds to the Spring 2017 survey for both Cohorts 1 and 2. There is no T2 observation for Cohort 3.
7. *Enterprise:* The entity by which the innovation is operating its scaling and/or sustaining efforts.
8. *Team:* The basic unit of ICL that works on a single enterprise. They are usually comprised of a Principal Investigator, Entrepreneurial Lead, and a Mentor, though some teams have more than one of each role.
9. *PI:* Principal Investigator
10. *EL:* Entrepreneurial Lead
11. *Mentor:* Mentor
12. *IP:* Intellectual Property.
13. *BMC:* Business Model Canvas, a technique used to pitch, plan, and scale an enterprise.
14. *MVP:* Minimum Viable Product, the stage of an enterprise that would be acceptable for early adopters to utilize.

Other Notes on Terminology and Language

- The terms users, customers, and adopters are often used interchangeably.
- Funding refers to a variety of different definitions depending on the context of the discussion. It usually refers to funding self-reported in the surveys, or data collected from the NSF.

[6] There was a pilot group of ICL teams that ran prior to cohort 1 and is not included in this study.

1. INTRODUCTION

1.1 OVERVIEW

I-Corps™ L (ICL) is a spin-off of the nationally recognized I-Corps™ course designed to foster commercialization of grant-funded projects. ICL is specifically targeted at STEM education-related innovations, while I-Corps™ focuses on technical innovations.[7] The ICL program has been delivered four times:

1. The Pilot ran in Jan/Feb 2014 with nine teams (funded through a grant to Univ. of Minnesota-Prime award DUE-1355431). This cohort is excluded from the current study.
2. Cohort 1 consisted of 24 teams that participated in Jan/Feb 2015 (also funded through UMN-EAGER DUE 1451245).
3. Cohort 2 ran in July/Aug 2015 with 19 teams (Through a prime award to ASEE)
4. Cohort 3 was run in July/August 2016 with 21 teams (Through a prime award to ASEE).

Like I-Corps™, ICL is both a reflection of and a strategy for an NSF agenda to extend the impact of initially funded grants associate with educational innovations.

Identifying factors that influence the success of ICL depends upon gathering critical survey and interview data from teams during and after their training. Course evaluations of ICL have focused on immediate course outcomes, including participant ratings of ICL curriculum, instruction and materials, as well as results on course-related outcome indicators and measures of future intentions regarding use of ICL concepts and development of innovations. Cohort evaluation surveys did not incorporate feedback from participants regarding the intermediate- or long-term outcomes on teams' innovations or personal/professional impacts.

Capturing the stories and documentation of how initially-funded NSF STEM education-related grants scale and sustain required collecting data about the opportunities that arose and the decisions team members made after the course ended. This research project, building upon the evaluation efforts to date, integrates cohort-based evaluation findings into broader, longitudinal examination of cohorts 1-3 (a longitudinal evaluation of the pilot group was independently conducted by ASEE with sponsorship from INTEL).

The objectives of this study were to:

1. Understand and document the outcomes of ICL with respect to sustaining and scaling innovations
2. Understand and document if and how the participating team members apply what they learned through ICL
3. Identify and define the start-up ecosystem in which ICL innovations scale and sustain.

This work began with the following, overarching questions:

Q1. **What are the outcomes of participation in ICL on the teams' innovations, the team members' personal and professional development?**

[7] NSF 14-095 & 15-050 - I-Corps™ L: Dear Colleague Letter – Stimulating Innovation in STEM Education

Q2. **What are the key features of and pathways within the ecosystem(s) in which ICL team members seek to successfully scale and sustain their STEM education-related innovations?**

1.2 Advisory Board

The study was guided by an advisory board that met annually. The first meeting was virtual (2015), and then co-located with the ASEE annual meeting (2016) and the OPEN conference (2016). Advisors were called upon individually to provide specific support through the project. The following people participated in an advisory role:

- Tom Byers, Stanford University
- Dean Chang, University of Maryland
- Rocio Chavela, ASEE
- Karen Crosby, Formerly NSF, Southern University
- John Krupczak, Formerly NSF, Hope College
- Sheri Sheppard, Stanford University
- Karl Smith, University of Minnesota
- Brian Yoder, ASEE

1.3 Organization of This Report

This report is the culmination of the two and a half years of research conducted under the EAGER grant. The report is divided into several sections.

- Chapter 2, Design and Methods. This section provides a simple overview of the study design, instruments, response rates, and analysis procedures.
- Chapters 3-7, Detailed responses to study questions: The findings from the various data collection activities are presented in five chapters. In some cases, additional explanation of the analytic approach will be included.

Table 1: Study Questions and Their Location Throughout the Report

Study Question	*Chapter*
How do innovations evolve from the time of the proposal through the months and years after the initial ICL training?	3. Teams; 8. Interview Study
What are the motivations, intentions, supports, and obstacles that influence innovation development?	
To what extent does ICL promote participants' intentions and behaviors that lead to broader adoption of the products of grants initially funded by NSF?	
How does participation affect team members' professional development, career trajectories, educational practices, research, collaborations and future actions?	5. Individuals
Which tools of evidence-based entrepreneurship most help ICL Principal Investigators and Entrepreneurial Leads identify approaches that are effective for STEM teaching and learning?	6. Mentors 7. Retrospective course feedback
What factors motivate team members to continue developing their innovations or arrive upon effective Go/No Go decisions post-training?	
In what way(s) do ICL team member activities rely upon and/or promote infrastructure within their institutions that facilitates the scaling and sustaining of their own and/or other learning innovations?	4. Institutions

- Chapter 8: Interview Study findings - Team Motivations, Intentions, Supports, and Obstacles: This chapter presents the findings from a set of interviews conducted to answer the second research question about the ecosystem in which teams are scaling and/or sustaining their innovations.
- Chapter 9: Conclusions and recommendations: This section will present the conclusions of the study team, implications, and recommendations.
- Appendices: The appendices include instruments, data read outs, and mid-study reports. The appendices serve as an archive of the research conducted under this project. Please contact SageFox Consulting Group to receive a copy of the appendices.

2. DESIGN AND METHODS

2.1 STUDY DESIGN

The study has been broken into two subparts corresponding to the two driving questions. Part 1 is a participant study, which examines the impact on the innovations and individuals that went through the ICL process (objectives 1 and 2) at two points in time (T1, T2). Part 2 addresses objective 3 in assessing factors that influence ICL innovations' sustaining and scaling activities.

Our proposed approach is illustrated in Figure A1, below.

Figure A1: ICL Longitudinal Study Strategy

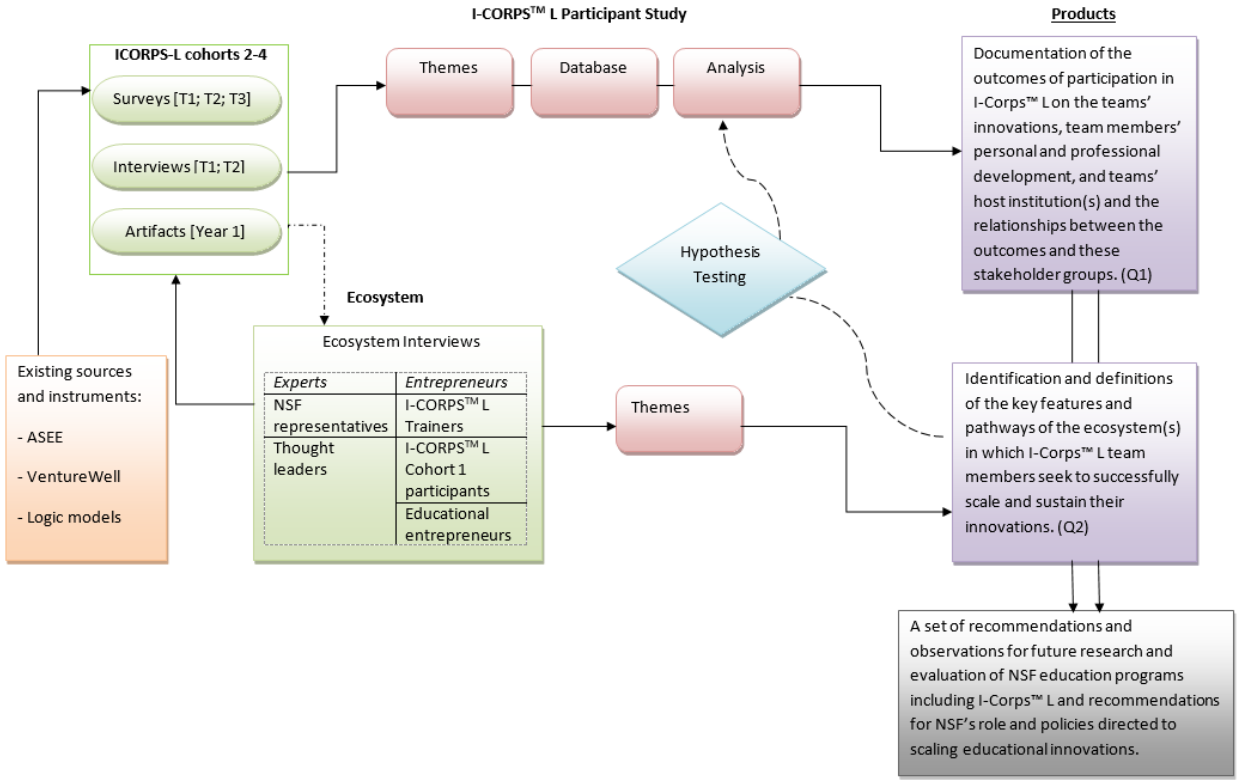


Table A1: Timing of and Participation in Study Activities

INTERVIEWS

	Exploratory Interviews (Fall 2015)	Participant interviews (Summer 2016)	Ecosystem interviews (2017)
Cohort 1 (24 teams) Trained in Jan/Feb 2015			
PI (25)	1		4
EL (25)	3		7
Mentors	1		1
Cohort 2 (19 teams) Trained in Jul/Aug 2015			
PI (20)	3	9	8
EL (18)	1		3
Mentors			1

SURVEYS

	Survey # 1 Dec/Jan 2015-16	Survey #2 Mar/Apr 2016	Survey # 3 Mar/Apr 2017		Mentor Study Mar/Apr 2017
			Long	Short	
Cohort 1 (24 teams) Trained in Jan/Feb 2015					
	T1		**T2**		
PI (25)	23		11	3	
EL (25)	24		17	0	
Mentors					15
Cohort 2 (19 teams) Trained in Jul/Aug 2015					
		T1	**T2**		
PI (20)		20	12	3	
EL (18)		18	11	1	
Mentors					10
Cohort 3 (21 teams) Trained in Jul/Aug 2016					
			T1		
PI (21)			12	3	
EL (21)			17	2	
Mentors					13
Some teams had more than one PI or more than one EL					

All teams are represented in the data, though not all teams submitted complete data. In one case, only the mentor provided information about a project. Of note, PIs and ELs participated in all cohort surveys (twice for Cohorts 1 and 2, and once for Cohort 3). To ensure full participation in the spring of 2017, a "short" survey was offered to non-respondents to the "long" 2017 survey in an attempt to boost the response rate and get basic information about the status of the team and innovation. Twelve participants took advantage of this option (Table A1). Mentors participated in one survey in the Spring of 2017. The PI/EL Spring 2017 long survey also included a module about the mentor component of the ICL model. The response rates for the 2015, 2016, 2017, and mentor surveys were respectively 94%, 100%, 71%, and 59%.

Analysis

The study team constructed an interactive database of variables by individual and by team and included the mentors' data. Using this database, the study team explored the relationship between the variables in an effort to answer the overarching research questions. The findings from these analyses are presented mainly in chapters 3-7 of this report.

Time Point 1 (T1) and Time Point 2 (T2)

Cohorts 1 and 2 each took the survey twice. This allowed for a longitudinal analysis across the two time points, (T1) and (T2). Table A2 defines the time points.

Table A2: Survey Time Points Across Cohorts

	Time point 1 (T1)	Time point 2 (T2)
Cohort 1	~ 11 months post-training	~ 2 years post-training
Cohort 2	~ 7 months post-training	~ 19 months post-training
Cohort 3	~ 9 months post-training	

2.3 Team-based Variables

In order to facilitate analysis at the team-level, aggregation of individual responses from the surveys is necessary. For most items, this is straightforward. Occasionally there were disagreements about the innovation between team members. To create one team-level response, we took the response from the PI and added information from the EL, if any question was missing data. If the PI did not take the survey, we used the EL's responses. For numerical entries, we took an average response; for open-ended items we took all responses; for "check all that apply," we took all responses.

How well the interview and mentor data are representative of the participating teams in each cohort are presented in Figures 2, and 3 respectively. The orange bar represents teams for which there is interview or mentor data, and the gray bar counts teams that do not. Both interview and mentor data are available for a relatively consistent proportion of teams across cohorts and times, with the exception of Cohort 3 interview data.

Figure A2: Availability of Interview Data by Cohort

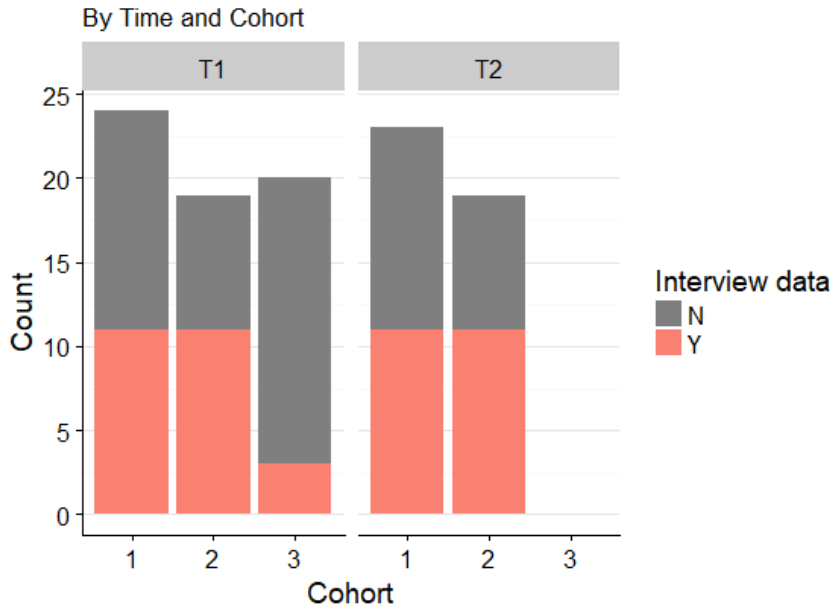
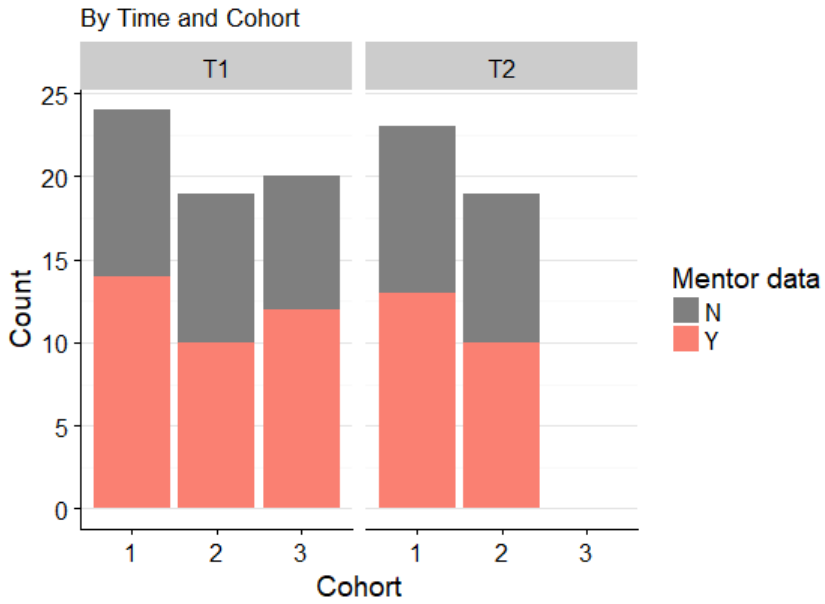


Figure A3: Availability of Mentor Data by Cohort



Figures 4 and 5 present the relative proportion of teams that have at least one EL (figure 4) or PI (figure 5) represented across each cohort and time period. The orange bar shows the number of teams that have an EL, PI, or both responding, and the gray shows those that do not. Figure 6 displays the proportion of teams where *both* are represented in our data; at T2, we have far fewer teams with both EL and PI responses, which is reflected in Figure 6.

Figure A4: Availability of EL Data by Cohort

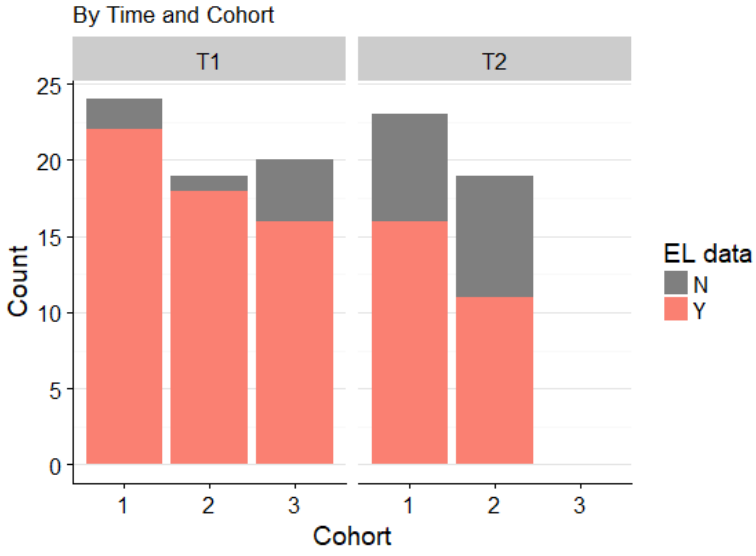


Figure A5: Availability of PI Data by Cohort

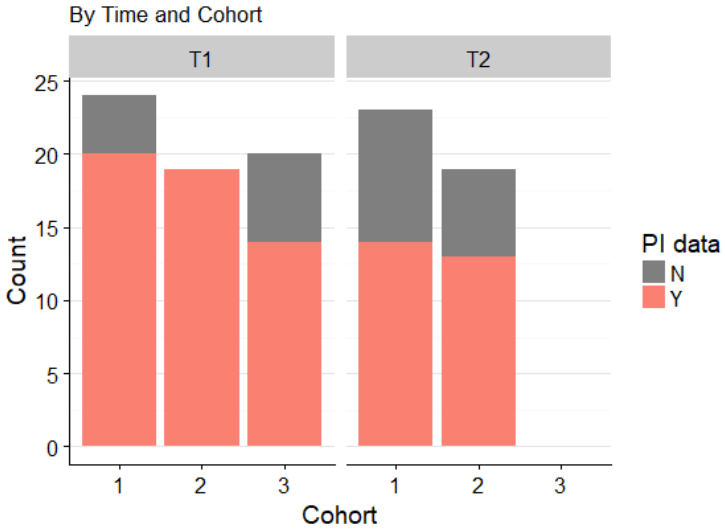
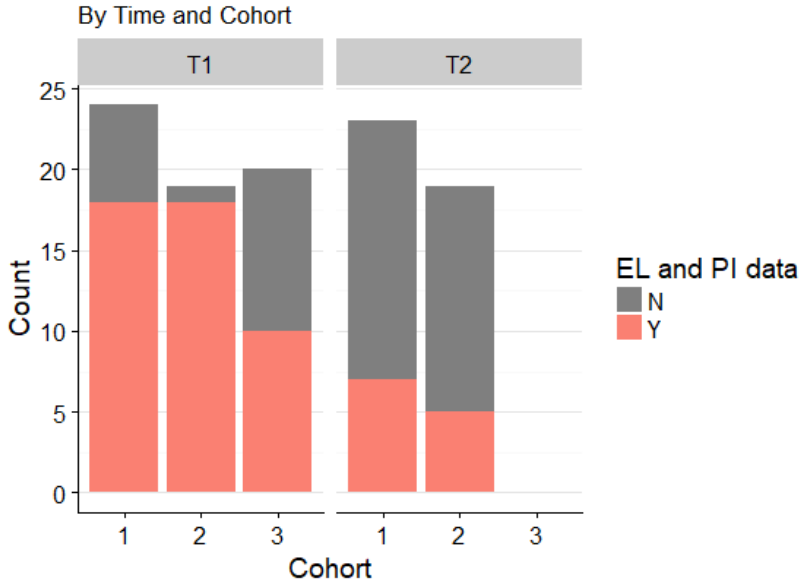


Figure A6: Availability of EL and PI Data by Cohort



Activity Index

To understand the relative progress of the projects a construct for "activity" was created from the T2 survey responses by cohort 1 and 2. Two variables contribute to the success construct:

1. Team member participation level
2. Status of the enterprise
    a. Presence and type of funding to work on the innovation
    b. Organizational structure in which the innovation resides
    c. Number of employees
    d. Customers (paying and non-paying)

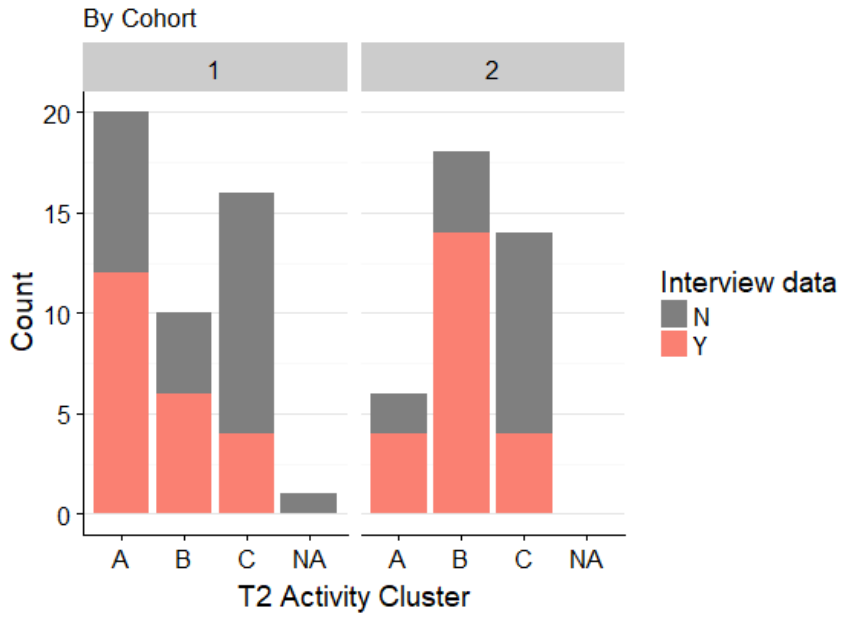
This analysis led to a designation of an “A”, “B” or “C” level team, with level “A” showing the most evidence of activity (see Chapter 3 for further explanation). The following Table shows the distribution of teams into the time point categories and activity level categories.

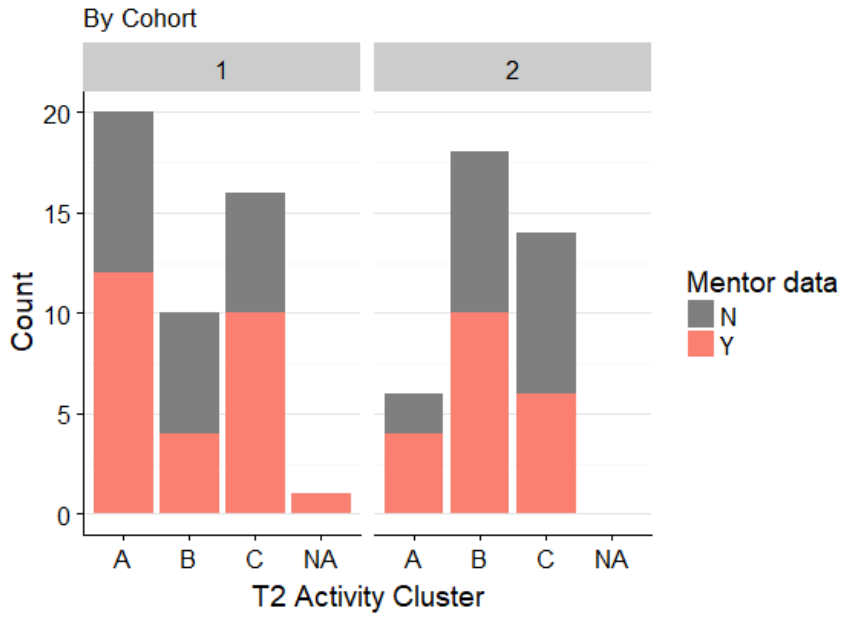
Table A3: Distribution of Cohorts by Activity Level

	Time point		**Activity Level**		
	T1	T2	A	B	C
Cohort 1	24	23	10	5	8
Cohort 2	19	19	3	9	7
Cohort 3	20	-	-	-	-
Total	**63**	**42**	**13**	**14**	**15**

The interviewed teams are mostly at high levels of activity, corroborating the selection process of interviewing very active teams. The mentor data are more equally spread across the categories. This is seen in Figures 7 and 8 below.

Figure A7: Availability of Interview Data by Activity Level





The Interview Study drew from the interviews with ICL participants and external experts. The data were analyzed for convergent and divergent themes, and a set of short case studies was developed to profile the variation among innovations and their ecosystems. This chapter explored team motivations, intentions, supports and obstacles.

Finally, preliminary data from the surveys and the ecosystem study were explored concurrently to understand the interaction between the innovation, the teams, and the context in which they seek to scale and/or sustain their activities.

2.3 Study Limitations

There are several limitations to the study that may have an effect on the conclusions.

Teams varied in terms of:

- *Criteria for selection*. Over the course of the ICL program NSF refined the selection criteria. Cohort 1 was selected by a group of NSF program officers on a highly individualized basis after phone interviews. Cohort 2 and 3 had more systematic set of criteria, including having an innovation that had a working "prototype" or curriculum of some sort and some initial data to show the basic efficacy of whatever was going to be scaled up, as explained by former program officer John Krupczak. Similarly, the project that was chosen for scaling up through ICL had to be closely related to the PI area of expertise. In the earlier cohorts, NSF noticed that the PIs may not have had a lot of expertise for the chosen project. Finally, teams were chosen based on the size of the "potential pivot space" in which Dr. Krupczak notes that there is an assumption teams will have to make a pivot, and thus cannot have a product that is locked into a relatively advanced stage of development.

- *Funding history.* An analysis of prior NSF awards shows that some projects that went through ICL have had significant prior investment, while others were more modest. The study team hypothesizes that those innovations that have had significant prior investment were more likely to have more mature innovations with greater evidence of efficacy. That said, not all PIs showed up through the NSF Award Search, though it is possible that they had received NSF support in the past, just not as a PI or Co-PI given the requirement that the application include a reference to a prior NSF award.
- *Entrepreneurial experience.* Team members varied in the amount of business, legal, and other knowledge related to scaling up educational innovations. This was particularly true for the ELs and the mentors. Experience was entirely self-reported and it is possible individuals interpreted the question response options differently.

The ICL courses varied in terms of:

- *Approach of the training team.* The first cohort of ICL participants experienced a course offered consistent with the canonical ICL approach in which feedback was "relentlessly direct." The backlash of participants to this approach was severe and it was changed in real time. That said, relentlessly direct instruction was not shown to significantly affect overall evaluation of the course. Rather, this instruction signaled diversity within each cohort in terms of individuals' motivations for sustaining and scaling. While the directness of instruction was modified in different cohorts, the significant shift was in the extent to which the curriculum was revised with each iteration to better address customer needs. Examples increasingly came from education/non-profit entities, double-bottom line was discussed, and entrepreneurs with educational innovations were recruited onto the teaching team.
- *Time of year of the ICL of the course offering.* Cohort 1 participated in the course during the spring semester while cohorts 2 and 3 were trained during the summer. The hypothesis of the study team is that cohort 1 was able to devote more attention to their innovation during the summer immediately following the training, while cohorts 2 and 3 completed the course and immediately returned to their academic positions, possibly devoting less attention to the scaling and/or sustaining of the innovation.

Timing of surveys for the cohorts

- *The timing of the survey was varied between cohorts*. Cohort 1 had more time before taking their second survey (T2) than Cohort 2 by 6 months
- *Cohort 1 had the benefit of a summer between training and survey 1* the other two did not, which as stated above, may have afforded different opportunities to promote their innovations.
- *Cohort 3 did not take a second survey during the study period* nor was it possible to get a third survey response from cohorts 1 or 2.

Response rates

- *Not all surveys had responses from both the PI and EL.* While at least one survey response was collected for each team at T1 and T2, not all teams had response from both the PI and El (figure

6). Given the differences that were often present, this meant the analysis was often based on only one view, not both.

- *In spring 2017 a "short survey" was offered* to entice those that had not otherwise taken the complete survey. For 6 teams, in Spring 2017, the only data collected was through the short survey which included a subset of the questions with a focus primarily on establishing team status.
- *The mentor survey had response rate* of 60%, which, given that some mentors were surveyed 2 years after participation, is decent. The responses were representative of cohorts, team and innovation activity and success.

Lack of specific outcomes for the program

- Based on the program solicitation (NSF DCL 14-095, DCL 15-050) and feedback from NSF officers and training leaders, there was not clarity on a specific set of objectives for the *learning* element of the ICL program. Broadly, there was a focus on supporting teams in sustaining and scaling their innovations and for the participants gaining an entrepreneurial mindset. The lack of more specific stated outcomes results in these findings being more descriptive than summative.

3. TEAMS

3.1 OVERVIEW

Understanding the consequences of ICL on the innovation required an analysis of *team* responses, rather than individual responses. This chapter presents and discusses results associated with the 63[8] ICL teams that form the basis of this study. All of the 63 teams that participated in the three cohorts had the potential to progress in terms of the team, the innovation and the enterprise associated with the innovation.

Data collected through three surveys (Table T1) along with a history of NSF grants associated with team personnel, form the basis of the analysis presented in this chapter. Surveys were designed to answer:

1. What is the current status of the team and the innovation?
2. What is the relative progress of each team in scaling and/or sustaining the innovation
3. What is the grant history for each team?
4. How do the survey results and the grant history together describe the consequence of ICL on the teams' efforts to scale and/or sustain their innovation?

Table T1: Team Summary: Responses by Cohort, Role and Time Period

	T1			T2		
	PI	**EL**	**Teams**	**PI**	**EL**	**Teams**
Cohort 1	23	24	**24**	14	17	**23**
Cohort 2	20	18	**19**	15	12	**19**
Cohort 3	15	19	**20**	-	-	**-**
TOTAL	**58**	**61**	**63**	**29**	**29**	**42**

The chapter is presented as four sections. The first describes the observed status of the 63 teams based on the surveys completed at two times relative to ICL participation. The first survey for each of the three cohorts is considered to be T1. For Cohorts 2 and 3, status at T2 is based on the Spring 2017 survey results. The key findings are:

- At T1 almost all of the teams (95%) have at least one person still actively engaged in working on the innovation and almost two-thirds of the teams have some form of active funding.
- At T2, three-quarters of the teams still have someone actively working the innovation and half still have some form of active funding.
- Variation in responses among the cohorts at T1 were most notable in terms of history and sources of funding, a condition that may relate to time available to work on the innovation and subsequently the likelihood of further advancement.

[8] One team in Cohort 3 was a "No-Go" (i.e., chose not to continue work to scale, sustain and/or commercialize their innovation) at that end of the ICL training and did not participate in this study.

The second section builds upon these data to create a three-level categorization of the relative progress of teams in cohorts 1 and 2 based on the team activity and state of the enterprise at T2. These results provide the potential of a predictive model and allow for subsequent analysis of team-related results. They also allow for considering whether other analysis (i.e., mentors and interviews) were typical or not of the distribution of teams. Key findings are:

- Teams that are designated as relatively inactive in T1 appear to be inactive in T2. In other words, there do not appear to be any teams that became active after a period of inactivity.
- Predicting where a team will be in T2 based on their position in T1 is difficult if they are moderately active or very active, but examination of scatterplots indicates that most teams remain at least somewhat active.
- Those teams interviewed (chapter 8) were on average more active than those that were not. This was a factor considered in selecting teams for interviews.
- The mentor data that form the basis of Chapter 6, derived from surveys, more closely represented the overall distribution of activity levels.

The third section incorporates the NSF grant history for the 63 teams based on those grants listed in NSF Award Search for PIs and ELs from 2000 through September 2017. Funding was considered in terms of timing relative to ICL (pre, concurrent and/or post) as well as level of funding from small (less than $300,000) to large (greater than $1,000,000). Key findings are:

- No evidence was found of pre-ICL funding for a little more than a quarter of the teams, which is surprising given that NSF's investment in ICL was to scale NSF-sponsored education innovations and the application required the listing of a prior NSF award.
- The amount of pre-I-Corps-L funding does appear to be a factor in predicting the subsequent progress of the teams, with 60% of those teams making most progress having had $300,000 or more of prior funding. However, there still were a significant number of teams that advanced without that initial level of investment.
- A majority (62%) of the teams had continuous funding during their ICL experience. Continuous funding appears to be important in providing the resources needed to move innovations forward. However, the absence of such funding is not seen as precluding further progress.
- The post-ICL funding shows that many of the PIs continued to pursue NSF grants, with 13 of the teams successfully obtaining new funding (17 grants worth over 14 million dollars) associated in some manner with their innovation. One of these teams had obtained two levels of SBIR funding.
- While there were relationships demonstrated between funding and subsequent progress, with 60% of the more active projects having significant pre- or post ICL, the absence of funding either pre-, during or post- did not clearly predict nor preclude that success.

Finally, in the fourth section these results are combined in a manner that permits contextualizing the survey results relative to the progress and grant history. Key findings are:

- In considering the relative role of the ICL team members, there is no association found with respect to the background and participation of the PI as there was little variation observed among the teams. Nor was there a relationship observed associated with the role and

contributions of the mentor. What does appear to be critical is the continued participation of the EL, especially at T2.

- The self-reported entrepreneurship-related skills and abilities prior to ICL for the associated team members was generally low. No correlation of these skills was found with subsequent progress of the teams.
- Most (90%) of the teams started in a host academic institution. Already by T1 a quarter of the teams report being in a new organizational structure with another 30% saying they anticipate being in a new structure a year hence. However, at T2 we see only 20% of the twenty-five active teams having made a shift.
- Most teams (69%) at T1 say that their innovation is both a product and a service. At T2 the teams showing the most activity and progress were most likely to be supporting a service or program-oriented innovation. This may be due to the greater likelihood of grant funding for services and programs.
- At T1 teams were equal in having higher education and K12 markets. By T2, the active teams were more likely to be in K-12.
- Having customers, (paying or non-paying) was strongly associated with the active teams at T2.
- Finding key financial resources was the most common and persistent obstacle teams reported. The other top obstacles were finding key personnel, lack of personal time, and determining viable revenue streams. Items not seen as obstacles were demonstrating educational efficacy and creating compelling value propositions. The most active teams at T2 had increased levels of problems associated with their home institutions.
- Customer discovery was the dominant activity of ICL, over three-quarters felt they had done this leading to identifying a value proposition that aligned with customers. For Cohort 2 and 3, 48% of the teams responding felt they had moved into a scaling phase, with 69% most active teams saying they were at this stage.

3.2 Basic Status of Teams

To what extent are teams and their innovations active at T1 and T2?

Almost all of the teams self-reported some degree of being active at T1. By T2 that percentage was still said to be about three-quarters. Evidence of team activity was based on whether participants said they personally were active or reported another member of the team active. This is presented in Table s T2 and T3 below.

Table T2: Teams and Reported Self-Involvment

Q: Are you still involved in the ICL project innovation?

	T1		T2	
	Yes	**No**	**Yes**	**No**
Cohort 1	23	1	18	5
Cohort 2	19	0	13	6
Cohort 3	18	2	-	-
Total Number	**60**	**3**	**31**	**11**
% of All Teams T1 (63) and T2 (42)	**95%**	**5%**	**74%**	**26%**

At T1, 95% of the teams had at least one person reporting being still actively involved with the ICL innovation. At T2, 74% of the teams reported the same with a larger percentage of Cohort 1 teams being active (75%) than Cohort 2 (68%).

Table T3: Teams and Reported Team Member Involvment

Q: Are the original members of the team still active in the Project?		**T1**	**T2**
		Yes	Yes
PI	Cohort 1	19	13
	% of Teams in Cohort at T1 (24) and T2 (23)	**79%**	**57%**
	Cohort 2	19	11
	% of Teams in Cohort at T1 (19) and T2 (19)	**100%**	**58%**
	Cohort 3	15	-
	% of Teams in Cohort at T1 (20)	**75%**	**-**
	Total	53	24
	% of All Teams T1 (63) and T2 (42)	**84%**	**57%**
EL	Cohort 1	18	14
	% of Teams in Cohort at T1 (24) and T2 (23)	**75%**	**61%**
	Cohort 2	14	9
	% of Teams in Cohort at T1 (19) and T2 (19)	**74%**	**47%**
	Cohort 3	15	-
	% of Teams in Cohort at T1 (20)	**75%**	**-**
	Total	47	23
	% of All Teams T1 (63) and T2 (42)	**75%**	**55%**
Both PI and EL	Cohort 1	15	12
	% of Teams in Cohort at T1 (24) and T2 (23)	**63%**	**52%**
	Cohort 2	14	9
	% of Teams in Cohort at T1 (19) and T2 (19)	**74%**	**47%**
	C3	14	**-**
	% of Teams in Cohort at T1 (20)	**70%**	**-**
	Total	43	21
	% of All Teams T1 (63) and T2 (42)	**68%**	**50%**
Mentor	Cohort 1	10	6
	Cohort 2	8	7
	Cohort 3	5	-
	Total	23	13
	% of All Teams T1 (63) and T2 (42)	**37%**	**31%**
	Note: Missing percent is "No", "Don't Know" or not reported		

When the PIs and ELS were asked about which team members were still active in the project, at T1, 84% of the PIs were said to be active, 75% of the ELs and 37% of the mentors. By T2 the participation was said to be at 57% of the PIs, 55% of the ELs and 31% of the Mentors. Teams with both the PI and the EL said to be active at T1 was 74% and at T2 was 47%.

The degree to which they were active was further defined by the amount of time they reported directly developing or implementing their innovation, as displayed in Table T4. For T1 70% of the teams reported either having one person working more than 10 hours or two people who are active to some extent. By T2 that percent dropped to 26% based on teams reporting.

Table T4: Teams and Time Spend on Innovation

Q. How much time is spent directly developing or implementing your innovation?

Pct. of Teams	**T1**				**T2**		
	C1	C2	C3	Total	C1	C2	Total
No time	0	5%	15%	6%	17%	32%	24%
Less than 10 hours	17%	21%	30%	22%	35%	42%	38%
Substantial Time (1 person > 10; 2+ >= 10)	83%	74%	50%	70%	35%	16%	26%

Note: More than 10 hours row aggregates several responses.

Another way of determining degree of activity was the reporting of team funding (Tables T5 and T6). At T1 63% of the teams reported the innovation was currently funded. At T2 that percent dropped to 50%. When asked whether they were *personally* funded to work on the innovations, responses were comparable to innovation funding status, with 65% in T1 and 43% at T2 reporting affirmatively

Table T5: Teams and Reported Innovation Funding Status

Q: Is your innovation currently funded?

	T1		**T2**	
	Yes	**No**	**Yes**	**No**
Cohort 1	18	4	13	5
Cohort 2	13	6	8	5
Cohort 3	9	9	-	-
Total Number	40	19	21	10
% of All Teams T1 (63) and T2 (42)	**63%**	**30%**	**50%**	**24%**

Table T6: Teams and Reported Personal Status

Q: Are you currently personally funded to work on the innovation?

	T1		**T2**	
	Yes	**No**	**Yes**	**No**
Cohort 1	16	8	12	8
Cohort 2	13	6	6	11
Cohort 3	11	8	-	-
Total Number	40	22	18	19
% of All Teams T1 (63) and T2 (42)	**63%**	**35%**	**43%**	**45%**

What is the evidence that there is an enterprise in place for the innovation?

Core to the status of the enterprise was funding and customers. The two items used to consider how active teams are (presented in Table T7, and Table T8) flow into this. Additionally, at T1 44% report that at least some of their funding is from a source other than that of a pre-ICL grant. This, however, varied widely by Cohort, with 67% having other sources at T1 compared to 42% of Cohort 2 and 20% of Cohort 3. By T2, 45% of the teams reported having some additional sources of funding with the difference between Cohort 1 and 2 being much smaller.

Table T7: Teams and Reported Funding Sources

Q: How is your innovation currently funded?

	T1				T2		
	Cohort 1	**Cohort 2**	**Cohort 3**	**Total**	**Cohort 1**	**Cohort 2**	**Total**
A grant started prior to I-Corps-L	*9*	*6*	*6*	*21*	*4*	*3*	*7*
Revenue from customers	7	5	4	16	2	5	7
A new external grant	5	2	2	9	6	2	8
Funding received from the home institution	4	5	0	9	4	2	6
Through a corporate partner	1	2	2	5	1	2	3
Contest winnings	0	0	2	2	0	1	1
Venture capital / Private investments	1	1	0	2	1	1	2
Other	7	0	1	8	1	1	2
Total teams with funding other than prior grant	***16***	***8***	***4***	***28***	***12***	***7***	***19***
% of All Teams T1 (63) and T2 (42) with funding other than grants	**67%**	**42%**	**20%**	**44%**	**50%**	**42%**	**45%**

Table T8: Teams and Additional Funding

Q: Have you sought additional funding since ICL?

	T1		T2	
	Yes	**No**	**Yes**	**No**
Cohort 1	-	-	13	4
Cohort 2	7	11	8	5
Cohort 3	8	10	-	-
Total Number	**15**	**21**	**21**	**9**
% of Cohort 2 and 3 Teams T1 (39) and Cohort 1 and 2 at T2 (42)	**38%**	**54%**	**50%**	**21%**

By T2, 50% of the teams had sought additional funding for their innovation, with Cohort 1 at 54% and Cohort 2 42%. This result could relate to NSF grant cycles and the timing of ICL training. A comparison for T1 was complicated by not asking this question of Cohort 1. For Cohort 2, however, it appears that it takes time to go after additional funds as only 38% of the Cohort 2 and 3 teams say they had done so by T1.

When asked if there were customers that had purchased or used the innovation, 56% of the teams reported either paying or non-paying customers at T1, and 55% of the teams at T2 said the same. This is seen in Table T9.

Table T9: Teams and Customers

Q: Do you have customers who purchased or used your innovation?

T1	**Any Customer**	Non-paying customers	Paying customers	Both	No
Cohort 1	**18**	9	6	3	5
Cohort 2	**7**	3	2	2	7
Cohort 3	**10**	5	4	1	8
Total Number	**35**	**17**	**12**	**6**	**20**
% of All Teams T1 (63)	**56%**	**27%**	**19%**	**10%**	**32%**
T2	**Any Customer**	Non-paying customers	Paying customers	Both	No
Cohort 1	**12**	7	3	2	4
Cohort 2	**11**	4	4	3	2
Cohort 3	**-**	-	-	-	-
Total Number	**23**	**11**	**7**	**5**	**6**
% of All Teams T2 (42)	**55%**	**26%**	**17%**	**12%**	**14%**

Note: The column "Any Customer" equals the sum of columns 2, 3, and 4. Customer categories are mutually exclusive

Another dimension to understanding the evolution of the enterprise was whether it was in the educational institution it had started, as presented in Table T10. At T1 44% were in a different organizational structure. At T2, based on teams reporting, it was 38%, which is not a significant change when taking into account the number of responses contributing to the base number.

Table T10: Teams and Current Organizational Structure

Q: In what organizational structure does your innovation currently reside?

	T1				T2		
	Cohort 1	Cohort 2	Cohort 3	**Total**	Cohort 1	Cohort 2	**Total**
The educational institution in which it started	13	14	12	**39**	12	9	**21**
A for-profit, independent company	5	3	6	**14**	5	1	**6**
A new entity under the educational institution's umbrella	1	0	1	**2**	1	2	**3**
A new home under another organization/partner	3	1	0	**4**	0	0	**0**
A non-profit, independent company	2	2	3	**7**	1	1	**2**
Other	1	2	1	**4**	4	1	**5**
Total not in educational institution in which it started	**11**	**9**	**8**	**28**	**10**	**5**	**16**
% of all teams not in educational institution in which it started in T1 (63) and T2 (42)	**46%**	**47%**	**40%**	**44%**	**42%**	**26%**	**38%**

Finally, teams reported whether they had a change in number of people working on the project. We asked this only in Spring 2017. For Cohorts 1 and 2 at T2 42% of the teams had increased number of people working full or part-time. For Cohort 3 at T1, only 33% of teams had an increase (Table T11).

Table T11: Teams and Change in Employees

Q: Change in number of people working on project

	Same or Decreased	Increased
Cohort 1	14	10
Cohort 2	11	8
Cohort 3	10	7
Total	**35**	**25**
% of All Teams with a change in the number of people working on the project (63) (4%NA)	**56%**	**40%**

3.3 Derivation of Team Constructs

3.1 Methods

These team-based data were compiled from the ICL surveys, and these data were coded according to a rubric that focused on items associated with team and enterprise status found in Tables T12 and T13 below. All aggregation and coding was done using R.

Table T12: Team Activity Index Components

Question	*Response scale*	*Conditional Response used for scale*
Approximately how much of your time is associated with each of the following? - Directly developing or implementing our innovation	0 hours per week	0 = no one spending time 1 = PI and/or EL <10 hours 2 = PI and/or EL >10
	up to 10 hours per week	
	11-20 hours per week	
	21-32 hours per week	
	More than 32 hours per week	
Are you still involved in the I-Corps-L project innovation?	Yes	0 = PI and EL no 1= PI or EL
	No, I left the team but the innovation is still being worked on	
	No, work on the innovation has stopped	
Are you currently personally funded to work on the innovation?	Yes, I still have the original funding	0 = PI and EL no 1 = PI or EL yes
	Yes, with new funding	
	Yes, with original and new funding	
	No	
Is your innovation currently funded?	Yes	0 = PI and EL no
	No	1 = PI or EL yes

Table T13: Team Activity Index Components

Question	*Response scale*	*Conditional Response used for scale*
Is your innovation currently funded?	Yes	0 = PI and EL no 1 = PI or EL yes
	No	
Are you currently personally funded to work on the innovation?	Yes, I still have the original funding	0 = PI and EL no or Yes with original 1 = PI or EL Yes with new or with original and new
	Yes, with new funding	
	Yes, with original and new funding	
	No	
How is your innovation currently funded?	A grant started prior to I-Corps-L	0 = PI and EL A grant started prior to I-Corps-L 1 = PI or EL any other answer than a grant started prior to I-Corps-L
	A new external grant	
	Funding received from the home institution	
	Revenue from customers	
	Venture capital / Private investments	
	Corporate partnership(s)	
	Contest winnings	
	Other	
In what organizational structure does your innovation currently reside?	The educational institution in which it started	0 = PI and EL The educational institution in which it started 1 = PI or EL other than the educational institution in which it started
	A new entity under the educational institution's umbrella	
	A new home under another organization/partner	
	A non-profit, independent company	
	A for-profit, independent company	
	Other	
How many people were working on the project (paid or unpaid) at the time I-Corps-L began? Currently?	*Numerical value, open end*	0 = Currently minus initial is zero or less than zero 1 =Currently minus initial is greater than zero
Since I-Corps-L have you sought additional funding for your innovation?	Yes/No	0 = PI and EL no 1 = PI or EL yes
Do you have customers who purchased or used your innovation?	Both paying customers and non-paying customers being supported through one of our grants or funds	0 = PI and EL no 1 = PI or EL Yes any type
	No	
	Non-paying customers being supported through one of our grants or other funds	
	Paying customers	

The data aggregation and coding were followed as above with one small alteration. While the vast majority of team-time responses that had more than one team member respond included at least one PI and EL, there were a few cases in which there were multiple responses, but they were all either a PI or EL. The PI and EL coding condition (e.g., item 1) was generalized to these circumstances as well. However, since this occurred in only three cases, an alternative coding for these cases would likely not result in any substantial differences.

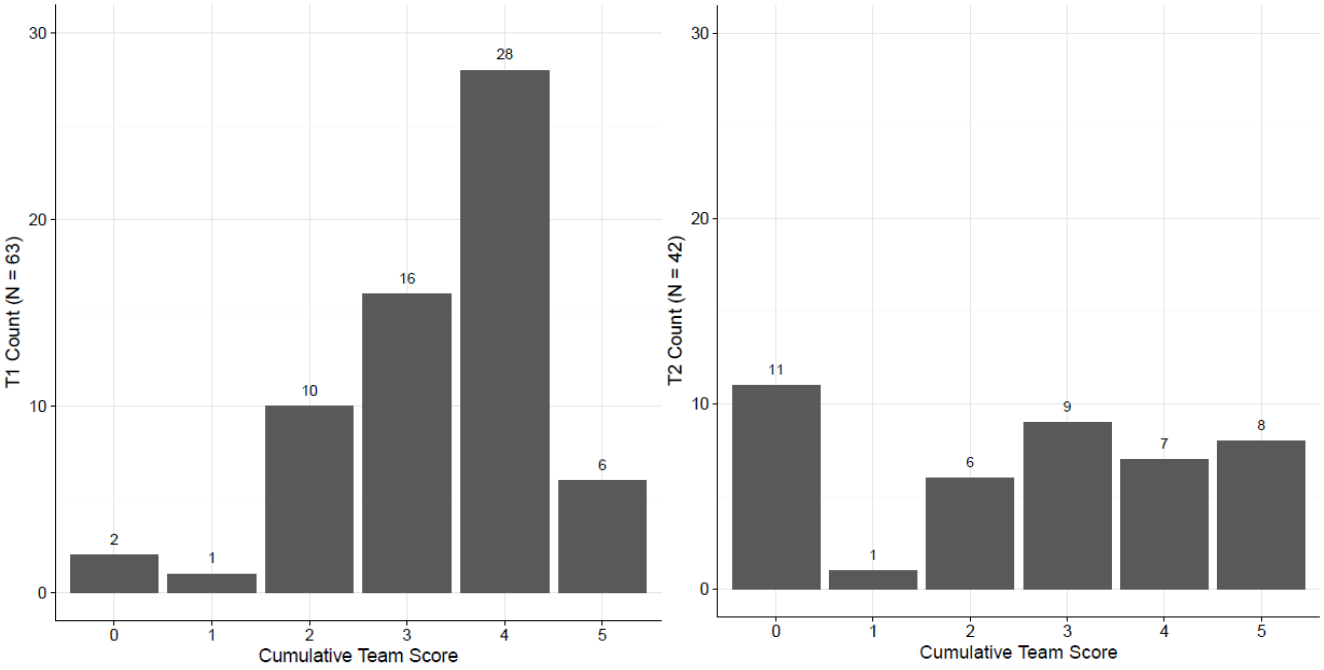
Once the individual variables of the coding scheme were generated, the four team activity values were summed, and the seven enterprise values were summed, in order to form two cumulative activity scores: one for the team activity, and one for the enterprise activity. For missing values, the respective variables were left blank in the individual team and enterprise items. Missing values were treated as zeros for these aggregates.

Team Activity and Enterprise Results

In the following set of plots, distributions of results for the team activity and enterprise scores are shown for two time periods; T1 which includes all three cohorts of teams (n=63) at a time within 9 months of I-Corps, and T2 (n=42) which includes results for Cohort 1 and 2 at 24 and 18 months post training.

Examination of the two separate cumulative sums (Figure T1 and T2) reveals two distinct observations that furthered our analysis.

Figure T1: Distribution of Team Scores at T1 (left) and T2 (right).



There appears to be consistent variation in the distribution of sums across time. While the two sums seem more or less normally distributed in T1, they form a more bimodal distribution in T2. Secondly, there is not that large of a difference between the enterprise and teams scores overall. Figure 3 presents the plots for the mean of these two cumulative sums in T1 and T2 respectively, and these distributions represent the distributions of the cumulative plots separately. This provides some evidence that the team and enterprise scores can be combined without overriding much difference in variation.

Figure T2: Distribution of Enterprise Scores at T1 (left) and T2 (right).

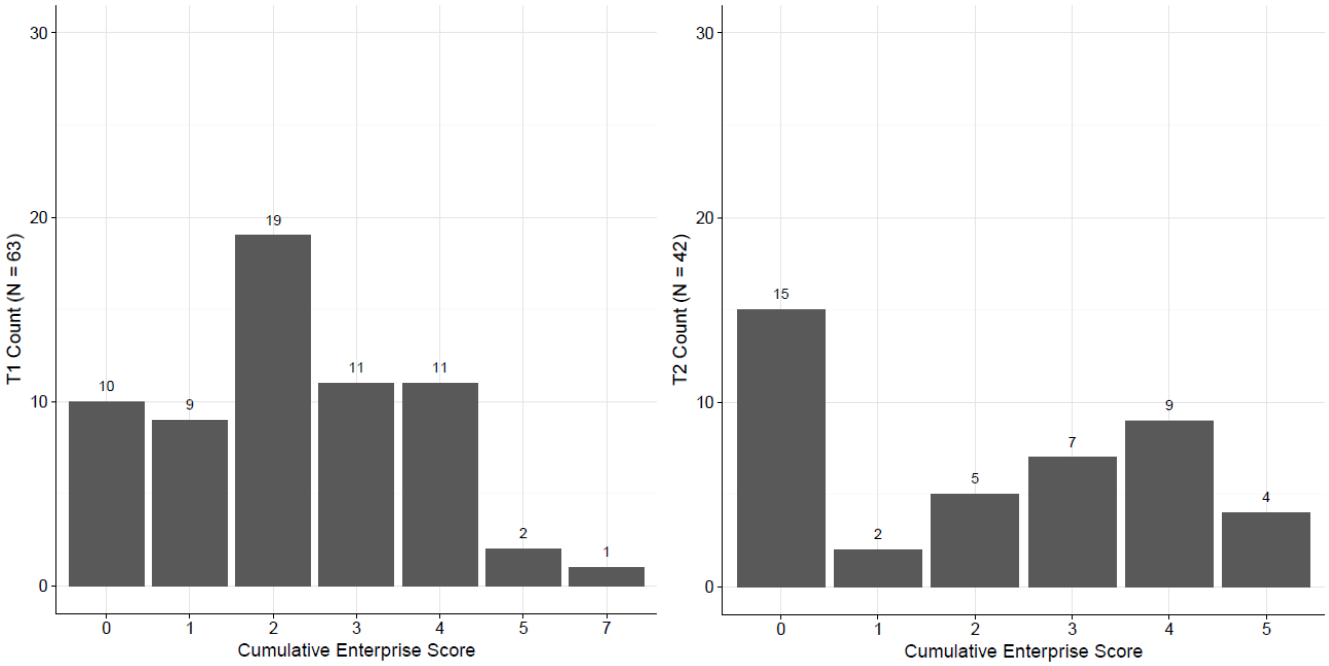
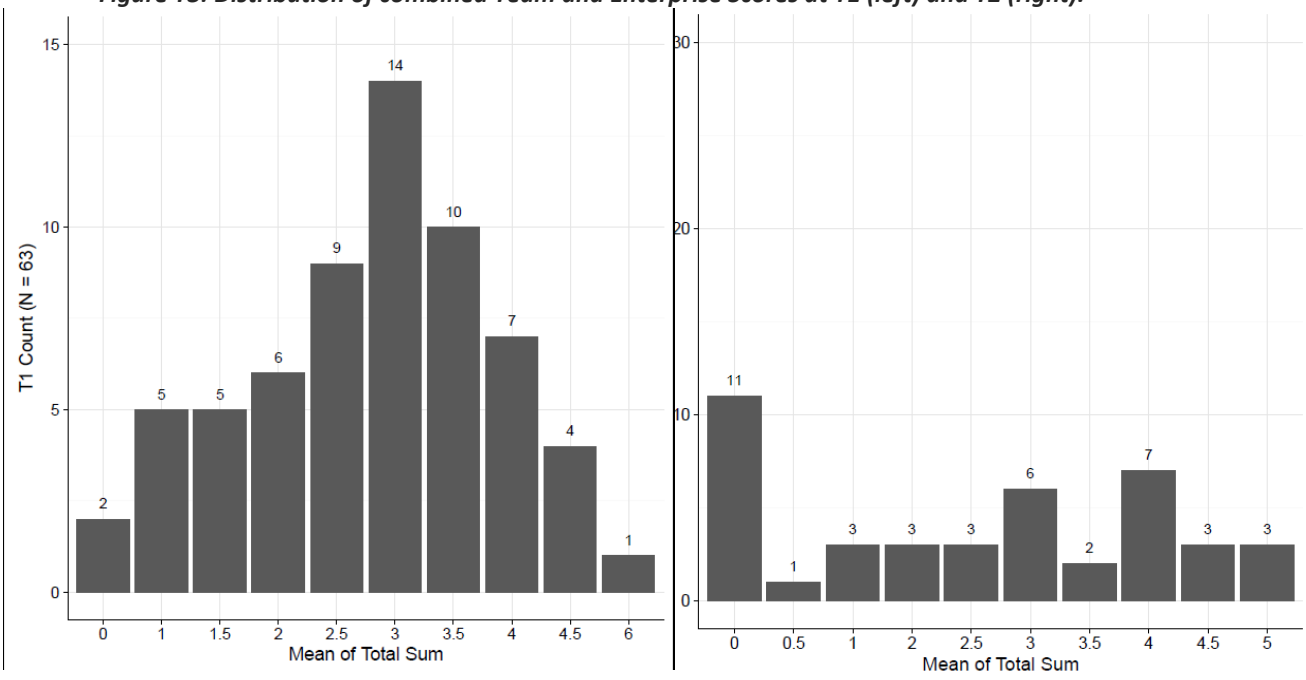
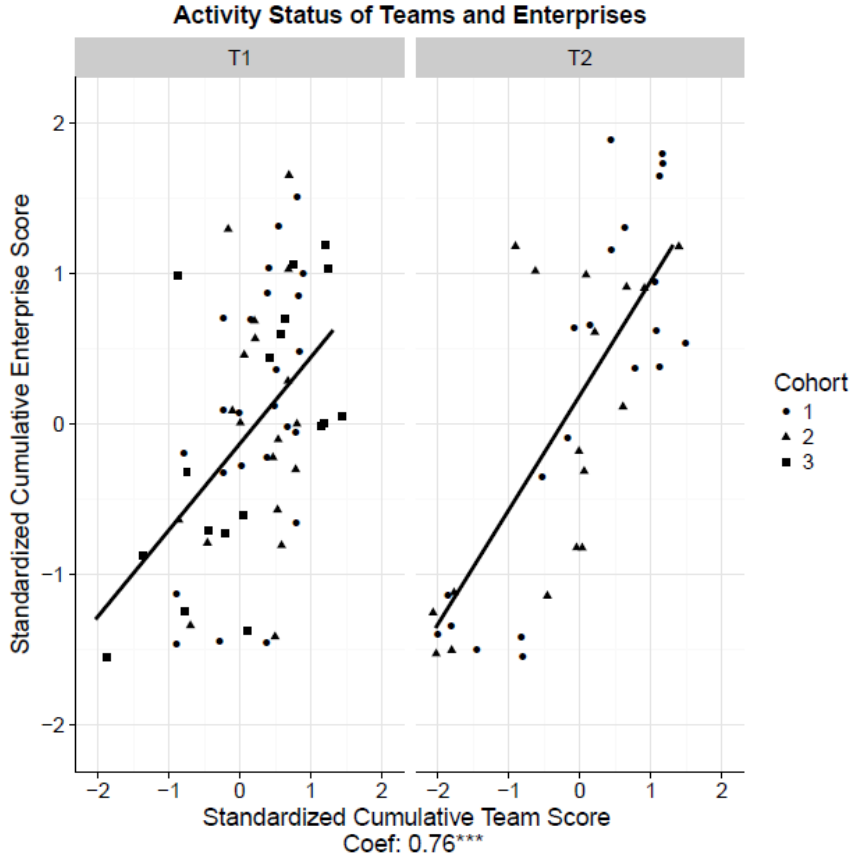


Figure T3: Distribution of combined Team and Enterprise Scores at T1 (left) and T2 (right).



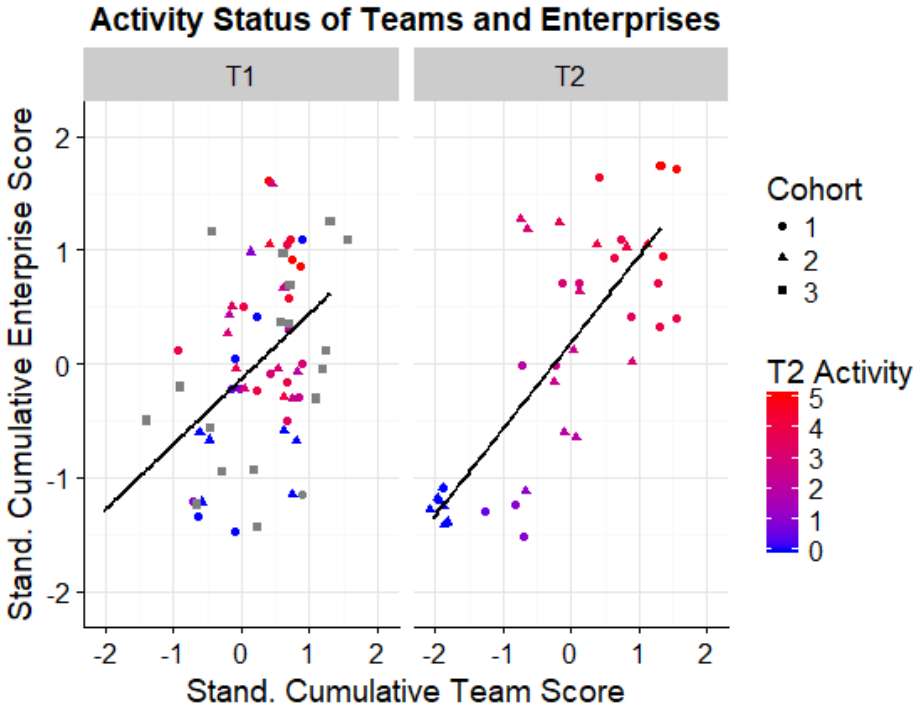
Furthermore, Figure T4 reveals a highly positive and strongly statistically significant linear relationship between the two standardized cumulative sums. This plot presents the cumulative team score on the x-axis and the cumulative enterprise score on the y-axis centered at zero. The coefficient of 0.76, which is close to one - along with the similarity in both the disaggregated histograms and the histograms of means above - suggests that team activity and enterprise activity are strongly synchronized, and that the variation lost through an aggregation of these two scores in order to develop a singular proxy of team activity would not result in a detrimental loss of information.

Figure T4: Correlation of Team and Enterprise Scores for T1 (left panel) and T2 (right panel).

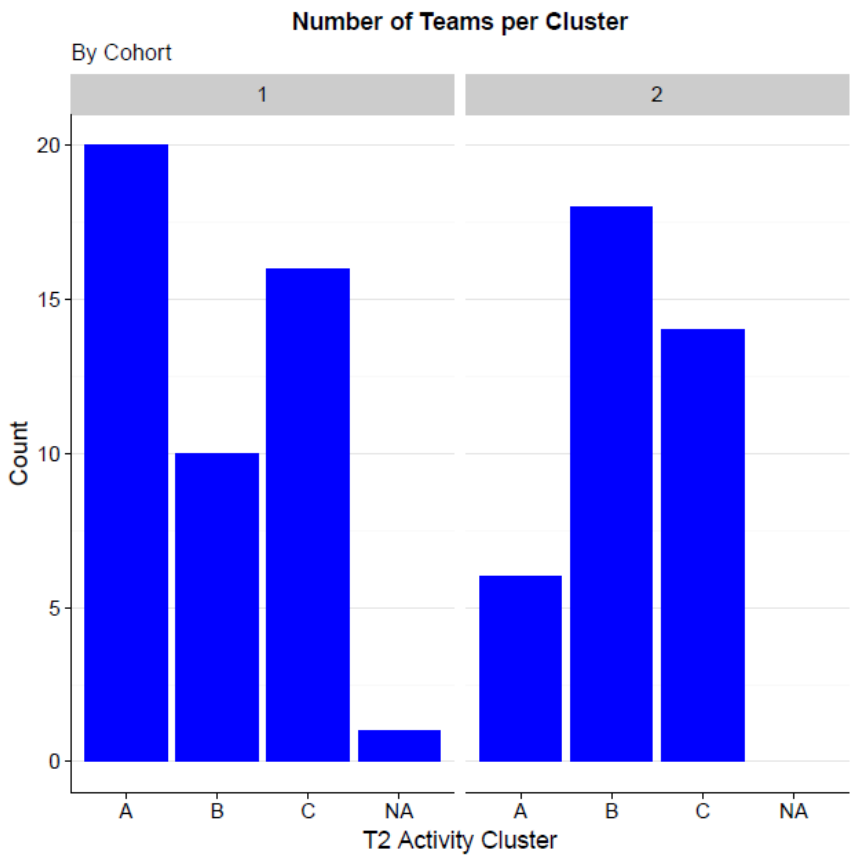


Based on these observations, a categorical ranking of each team was developed based on the team-enterprise activity level distribution of each team at T2. This distribution is based on the visually observed clusters both in the frequency bar graphs of T2 (Figure T3) individual cumulative and mean sums, as well as the scatterplots comparing the distribution of these sums across time (Figure T4). Three categories of T2 activity are easily identified in Figure T5, which replicates Figure T4 but adds a color dimension representing the mean value on a continuous scale. Based on these scatterplots, three categories of general activity in T2 can be discerned: very active, moderately active, and not active. These assignments are based on the visual clustering of these data.

Figure T5: Correlation of Team and Enterprise Scores with continuous color scale of mean at T1 (left panel) and T2 (right panel).



The bimodal distributions as well as the color gradient in the plots suggest coding the team-enterprise mean value according to the following scheme: category C is coded as any mean value in T2 less than 2, category B as any mean value between 2 (inclusive) and 4, and category A as any mean value greater than or equal to 4. Figure T6 presents the frequencies of this category by cohort. Note that two time periods are reported in the Figure. According to these assignments, teams that fall into the "A" category can be interpreted as demonstrating a high level of activity, and "B" teams can be interpreted as teams with intermediate or mixed levels of activity. Teams that receive a "C" demonstrate little to no evidence that they are actively pursuing their innovation.



s 1 and 2.

The resultant categorization of Cohort 1 and 2 teams at T2 into A (n= 13) B (n=14) and C (n=15) designations along with the aggregated status of teams from all three cohorts at T1 is shown in Table T14.

Table T14: Distribution of Cohorts by Activity Level

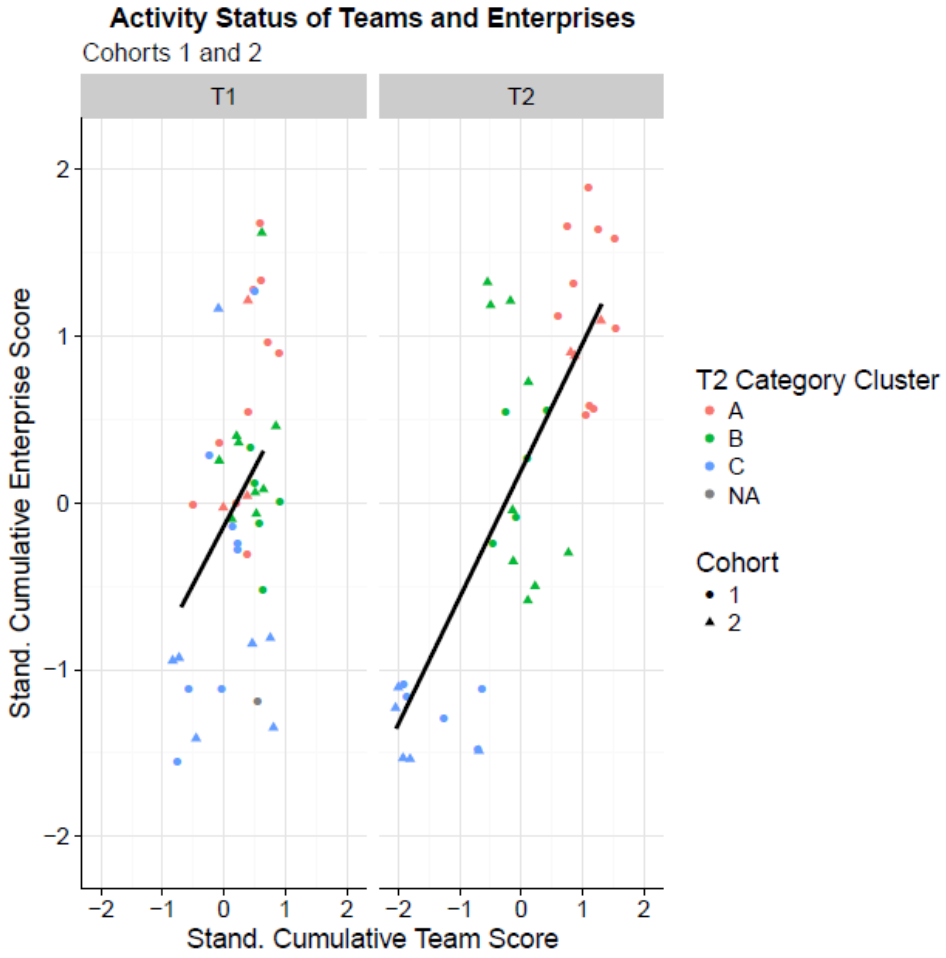
	T1	T2	A	B	C
Cohort 1	24	23	10	5	8
Cohort 2	19	19	3	9	7
Cohort 3	20	-	-	-	-
Total	**63**	**42**	**13**	**14**	**15**

3.4 Discussion

Predictive Model of Team Activity

Figure T7 presents the scatterplots of these sums and categorical rankings by time and cohort, with cumulative team score on the x-axis and cumulative enterprise score on the y-axis. The black line represents the estimated linear fit between the two variables, the colors present the T2 category cluster, and the shape represents the Cohort. As can be observed in the right-hand panel, the mean generalized into the three categories seem to accurately represent the respective T2 activity clusters presented in the scatterplots referenced above.

Figure T7: Correlation of Team and Enterprise Scores with Category Cluster designation (A,B,C) for Cohorts 1 and 2 in T1 (left panel) and T2 (right panel).

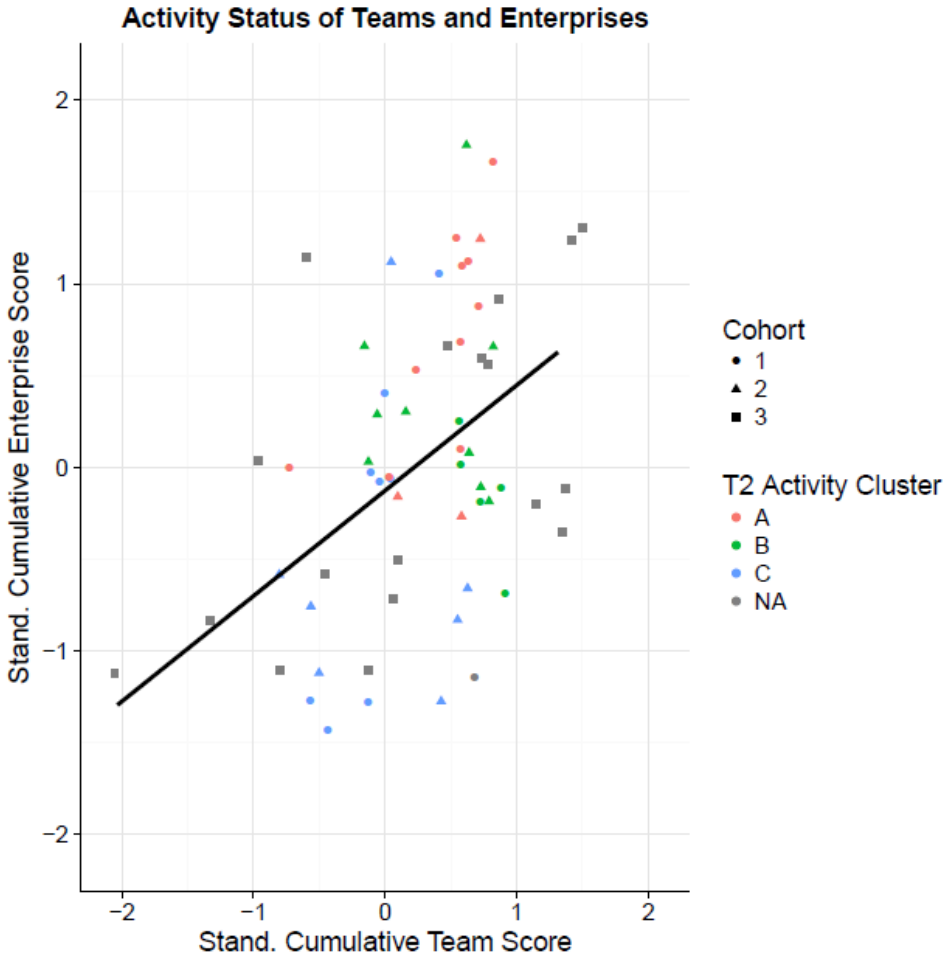


These T2 category clusters are then cast backward in time - to T1 in the left panel - in order to visualize the level of activity these teams had in T1 to approximate a predictive model of T2 activity based off of activity in T1. As can be observed, the vast majority of those ranked as category C in T2 were also at levels of low activity in T1, suggesting that those teams that were inactive in T1 are not likely to undergo a surge of activity in T2. There are also a handful of category C teams that were active in T1, however, which suggests that there is some inflow into inactivity from T1 to T2, even for teams that were actually quite active early on. Additionally, most of the teams that were active in T2 were also active in T1, although to varying extent - there is a fair amount of variation between T1 and T2 with regards to categories A and B. If a team is active to any extent in T1, there is no obvious way to predict their level of activity in T2 unless they are already very inactive.

Figure T8 overlays cohort 3 onto the T1 scatterplot in an effort to apply this basic predictive model. The distribution in T1 is quite similar to cohorts 1 and 2. We can comfortably conclude that those teams that are not currently active in T1 for cohort 3 will remain inactive in T2. However, like the other two cohorts, it is difficult to say where the teams with moderate to high activity levels in T1 will be within the next

year; some of them may continue to flourish, while others could migrate to lower levels of activity and arrive at category C.[9]

Figure T8: Category Cluster Designation for Cohorts 1 and 2 with addition of Cohort 3 data (T1 only).

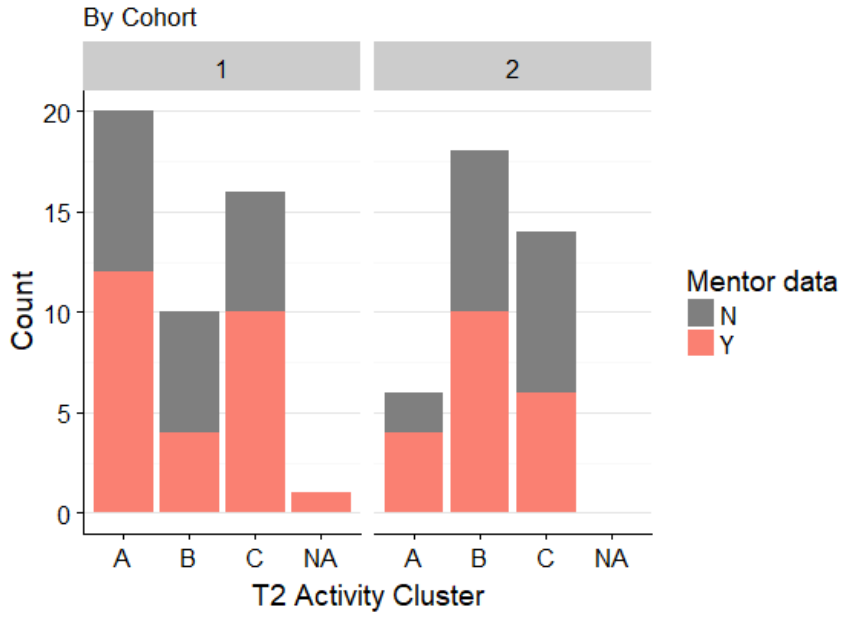


Representation of Interviews and Mentors

Two of the data sets used to formulate findings for the overall project were based on lower response rates (The Spring 2017 Mentor survey) or sampled population (The PI interviews). Figures T9 and T10 present tabulations of whether or not there exists mentor or interview data, respectively, based on the team-enterprise categorical assignment. The interviews seem to come from teams that are more active. This is a critical result, and confirms that the collection methods of the interview data did in fact select the most active candidates. The average team and enterprise sums for those teams that were interviewed are in fact higher for the teams overall. The mentor data, however, is much closer in activity rating as the overall sample, which is indicated in the small difference in means between those that have mentor data and those that do not, as well as visually depicted in Figure T9.

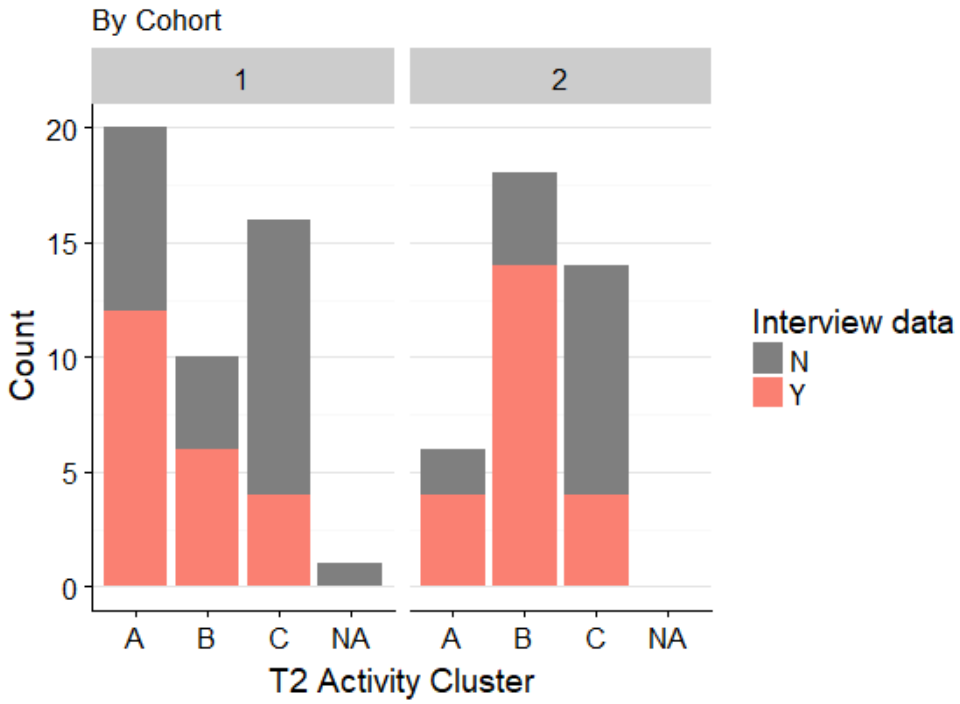
[9] For this reason, A and B teams are often aggregated in the succeeding section and analyzed jointly.

Figure T9: Distribution of Mentor data by Team Categorization for Cohorts 1 (left panel) and 2 (right panel).



This analysis provided a means of identifying active teams, as well as tracing those teams across time to generate the underpinnings of a predictive model of activity across time. It generated a data set that provides proxies for various types of activities, as well as summative measures of overall activity, which could be useful in additional team-level focused analyses. The most summative index, derived from the separate team and enterprise cumulative sums, categorizes T2 activity into three levels, and suggests that besides those teams that are very inactive, it is difficult to detect how active a team will be in T2 based solely on their T1 activity. This index forms the basis in the remainder of this chapter in answering a variety of questions in relation to team outcomes, and factors that may be associated with being responsible for those outcomes and those that may consequential to those outcomes.

Figure T10: Distribution of Interview data by Team Categorization for Cohort 1 (left panel) and 2 (right panel).



3.5 Grant and Funding History of ICL Teams

I-Corps™ L teams were by design intended to bring to the I-Corps process innovations developed as part of prior NSF funding. This chapter investigates the relationship of NSF funding to team and enterprise evolution, specifically:

1. What was the NSF-related funding history of teams prior to ICL?
2. How important is pre-ICL funding in developing the innovation and the team's experience?
3. Did teams obtain new NSF funding post-ICL and was that funding a consequence of
4. Is there evidence that level of investment was associated with outcomes?

About the Data

A database of NSF awards was created based on the history of funding of the ICL PI's and EL's that covered a time period from 2000 through September 30, 2017. Awards were noted whether the PI or EL were PI's or co-PI's. Almost all of the awards were associated with the PI. Of the 51 teams with some funding, 8 had EL's as being either PI's or Co-PI's with the EL commonly a Co-PI with the PI.

Awards that appeared to be primarily focused on scientific research unrelated to education or the team's innovation were excluded. The analysis excluded the ICL award as all teams had that funding.

For each team it was noted whether teams had funding prior to ICL that was no longer active, funding continuous through the period of ICL and new funding awarded post ICL. For the later, efforts were made to determine whether the new funding was directly associated with the ICL team's innovation.

Also coded was the magnitude of total award funding at three levels, less than $300,000, $300,000 to $1,000,000 and more than $1,000,000. It should be noted that the size of the grants may not necessarily correlate with the specific ICL team's innovation but rather more likely is related to the funding history of the team. These variables are defined in Table T15 below.

Table T15: Description of Grant Variables

NSF Grant Related Variables	***Conditions***		
	Grant start time	Grant end time	Possible values
Pre-ICL	Before ICL	OPEN	0 = None; 1 = between 0 and 300K; 2 = between 300K and 1000K; 3 = greater than 1000K
Concurrent-ICL	Before ICL	After ICL	Same as above
Post-ICL	OPEN	After ICL	Same as above
New Post-ICL	After ICL	After ICL	Y = Yes; N = No
Continuous Funding	Pre-ICL, Concurrent-ICL, and Post-ICL must equal either 1,2, or 3		Y = Yes; N = No
Substantial Continuous Funding	Pre-ICL, Concurrent-ICL, and Post-ICL must equal either 2, or 3		Y = Yes; N = No

Note: Only NSF grants were considered. NSF grants not related to project innovation were also excluded. Start and end times depends on cohort.

Funding History Results

Given that a significant intention underlying I-Corps™ L is to encourage teams to sustain and scale NSF-funded education innovations and that the application required a reference to a prior award, it is surprising to see that for 28% of the teams, no prior NSF funding was found for the PI or EL. Table T16 shows the funding history of ICL teams by cohort. Cohort 2 stands out as having the highest level of pre-ICL funding (reflecting the shift in selection criteria). Cohort 1, with the longest time period post-ICL, not surprisingly also shows the greatest success in obtaining post-ICL funding through NSF awards.

Table T16: Summary of Grant Funding

	Any funding	Any Pre-ICL funding	Continuous Funding	Any Post-ICL funding
Cohort 1 (n=24)	83%	71%	42%	71%
Cohort 2 (n=19)	89%	84%	37%	63%
Cohort 3 (n=21)	67%	62%	38%	67%
Total (n=64)	**80%**	**72%**	**39%**	**67%**

Tables T17-T19 show the relative level of funding teams had prior, concurrent with and post-ICL. Percentages are for all teams in the cohort or total of 63 teams.

Cohorts 1 and 3 had the largest number of teams with pre-ICL funding of a million dollars or more, but Cohort 2 had the most teams with some pre-ICL funding (Table T17).

Table T17: Pre-Funding Magnitude

	No pre-funding	level 1 pre-funding	level 2 pre-funding	level 3 pre-funding
Cohort 1 (n=24)	29%	21%	4%	46%
Cohort 2 (n=19)	16%	26%	32%	26%
Cohort 3 (n=21)	38%	19%	10%	33%
Total (n=64)	**28%**	**22%**	**14%**	**36%**

The importance of continuous funding is that it provides funds for team members to potentially continue to work on the innovation during and after the I-Corps™ L. Of those with NSF funding, Cohort 3 had the highest level of continuous funding, in large part because that cohort's includes only 13 months of post-ICL versus the other cohorts for which the post period covers 34 months (Cohort 1) and 25 months (Cohort 2).

Table T18: Concurrent Magnitude Funding

	No concurrent funding	level 1 concurrent funding	level 2 concurrent funding	level 3 concurrent funding
Cohort 1 (n=24)	38%	21%	4%	38%
Cohort 2 (n=19)	37%	16%	32%	16%
Cohort 3 (n=21)	38%	14%	10%	38%
Total (n=64)	**38%**	**17%**	**14%**	**31%**

The Post-ICL funding is indicative of both continued effort associated with innovations associated with prior funding and new funding that may be not be associated with the ICL team's innovations. For some teams, obtaining new NSF funding was seen as the best means of sustaining their team and scaling their innovation.

Table T19: Post-Funding Magnitude

	No post-funding	level 1 post-funding	level 2 post-funding	level 3 post-funding
Cohort 1 (n=24)	29%	21%	4%	46%
Cohort 2 (n=19)	37%	11%	32%	21%
Cohort 3 (n=21)	33%	19%	19%	29%
Total (n=64)	**33%**	**17%**	**17%**	**33%**

New NSF Grants Associated With Participation

Thirteen of the sixty-three (21%) ICL teams appear to have successfully been awarded 17 new NSF grants totaling over 14 million dollars that are either a direct consequence of or were strongly influenced by the ICL experience (Table T20). These new grants were identified by considering the nature of the award, as described in the NSF Award abstract, and the due date of the relevant program call in relationship to the timing of ICL participation.

Table T20: New Post-ICL NSF Grants likely influenced by ICL participation

	No. of Teams	No. of Awards	NSF Programs	Total Award Amount
January/February 2015 (Cohort 1)	5	7	DRK-12, HCBU, HRD, IUSE, SBIR 1, SBIR 2, TUES Type 3	$ 5,109,603
July/August 2015 (Cohort 2)	2	3	ATE Program, DRK-12, I-Corp Site	$ 2,112,812
July/August 2016 (Cohort 3)	6	7	ATE Center, HRD, IUSE (3), PFI, RET	$ 6,925,877
Total	**13**	**17**		**$14,148,292**

Almost all of the awards were within the Education and Human Resources (EHR) Directorate. One team has successfully obtained both an SBIR Phase 1 and 2. The PI from another has subsequently received an I-Corps™ Site award.

Relationship of Grant History to Team and Enterprise Status

In the section 3, a categorization of the teams was based on a consideration of factors associated with the degree of team activity and the status of the enterprise. These values are used here (Tables T21-T23) to consider the role of funding in affecting status and the relationship of status to potential post-ICL funding.

The relationship of pre-funding level to categorization appears to be fairly strong (Table T21). While 60% of the teams categorized as A or B had pre-funding of $300,000 or more, 60% percent of the teams categorized as C had funding less than $300,000. As pre-funding is likely to indicate a combination of resources that went into developing the innovation and building the team experience, this seems like a reasonable observation. It should be noted however, that the absence or limited nature of pre-funding does not appear to be a limiting factor as 31% of the A teams had no observable record of pre-funding.

Table T21: Relationship of Pre-ICL NSF funding to categorization of team and enterprise status for Cohorts 1 and 2

		Pre-ICLL NSF Funding Levels			
Status at T2	**n**	**None**	**<300K**	**300K-1M**	**>1 M**
A	13	31%	8%	8%	54%
B	14	21%	21%	21%	36%
C	15	20%	40%	20%	20%
Total	**42**	**24%**	**24%**	**17%**	**36%**

Lack of continuous Funding (Table T22) appears to be a strong factor in defining those team designated as C, with the lowest team activity and enterprise status. In the absence of continuous funding, teams are less likely able to commit the time to move the innovation forward. However, when we look at the B and C teams, we do see evidence of more activity and enterprise development that includes many teams that did not have continuous funding, suggesting other factors may be associated with their progress.

Table T22: Relationship of Continuous NSF funding to categorization of team and enterprise status for Cohorts 1 and 2

		Substantial Continuous NSF Funding	
Status at T2	**n**	**No**	**Yes**
A	13	54%	46%
B	14	43%	57%
C	15	87%	13%
Total	**42**	**62%**	**38%**

Table T23 shows the categories against whether or not a team continued to receive funding after ICL, whether with new grants or grants that extended past the ICL experience. The vast majority of teams did not, but those with an A rating were more likely to have done so than the others. Since more A teams had substantial pre-funding than post-funding, it may be the case that a fair number of A teams started with high funding, and then used the ICL experience to develop alternative revenue streams and as a result did not need to pursue grants in the post period.

Table T23: Relationship of Post-ICL NSF funding to categorization of team and enterprise status for Cohorts 1 and 2

		Post-ICL NSF Funding Levels			
Status at T2	**n**	**None**	**<300K**	**300K-1M**	**>1 M**
A	13	38%	0%	15%	46%
B	14	29%	14%	29%	29%
C	15	33%	33%	7%	27%
Total	**42**	**33%**	**17%**	**17%**	**33%**

Of those teams that made the most progress in Cohorts 1 and 2 (categorized as A or B), more than 60% had pre-funding of $300,000 or more.

Funding Summary

The ICL Teams demonstrate a diverse pattern of NSF funding from pre-ICL to post that in part is associated with team and enterprise outcomes.

- No evidence was found of pre-ICL funding for 28% of the teams, surprising given that NSF's investment in ICL was to scale NSF-sponsored education innovations and prior funding was a part of the application. That said, some teams are coming through I-Corps nodes or sites, which gives them an NSF lineage. Also, some teams may have their origins in NSF projects where the ICL team members were not a PI or Co-PI.
- The amount of pre-ICL funding does appear to be a factor in predicting the subsequent progress of the teams with 60% of those teams making most progress having had $300,000 or more of prior funding. However, there still were a substantial number of teams that advanced without that initial level of investment.
- Many of the teams (62%) had continuous funding during their ICL experience. The role of continuous funding appears to be important in providing the resources needed to move innovations forward but the absence of such funding is not seen as precluding further progress.

- The post-ICL funding shows that many of the PI's continued to pursue NSF grants with 13 of the teams successfully obtaining new funding (17 grants worth over 14 million dollars) associated in some manner with their innovation. One of these teams had obtained two levels of SBIR funding.

While there were relationships demonstrated between funding and subsequent progress, with 60% of the more active projects having significant pre- or post ICL, the absence of funding either pre-, during or post- did not clearly predict nor preclude that success.

3.6 Relationship to Progress of Teams and Their Innovations

This section explores the relationship of team status to an array of factors that are associated with the nature of the team and the innovation, the capabilities the team brought to the ICL experience, the organizational structure supporting the team over time, the obstacles team faced and finally the stage of development that the teams reported at T1 and T2.

Team characteristics

The demographics and attitudes of the team participants is explored in the chapter "Individuals". In this section we consider the extent to which a relationship can be found between those results and the advancement of the teams.

The background of the PIs does not significantly vary among team as most are faculty members. For the ELs there is a greater diversity with no obvious pattern emerging relating role to team status (Table P2). What does appear to be relevant to team success is whether the ELs are said to be active at T2. Whether this is a consequence of team progress or associated with opportunities associated with progress is difficult to distinguish (Table T24).

Table T24: Percent of Teams by Activity Index saying EL is active

	A (n=13)	B (n=14)	C (n=15)
T1	92%	79%	59%
T2	92%	57%	20%

The role of the mentor also does not appear to be associated with relative progress, either in their degree of active nor in the nature of support provided (see chapter 6).

Team members were asked to rate themselves with respect to a number of dimensions of entrepreneurship skills and abilities prior to ICL (Table T25). The results, compiled at the team level, show an overall pattern of relatively modest ratings on most items. On a scale of 0 to 3, nothing exceeds 1.5 on average. The top items are some modest level of knowledge of commercialization and similarly modest ratings associated with scaling and sustaining an educational innovation or the associated ecosystem. No correlation of these skills appears to be associated with the subsequent progress of the A and B Teams vs. C.

Table T25: Activity Index and Prior Experience

Q. Prior to ICL, how would you rate where you are with the following? (0 = None; 3 = A lot)

	Avg. T1	Null (n=20)	A (n=13)	B (n=14)	C (n=15)	Max n
General business knowledge as relevant to commercialization	1.5	1.1	1.3	2.1	1.9	63
Scaling and sustaining an educational innovation	1.5	1.3	1.4	1.8	1.8	44
Familiarity with the ecosystem in which an educational innovation scales and sustains	1.3	1.3				20
General legal knowledge as relevant to commercialization	1.3	1	1.2	1.6	1.4	63
Commercializing an innovation	1.1	0.9	1.1	1.2	1.4	63
Securing IP	1.1	0.7	1.1	1.2	1.6	63
Scaling and sustaining an innovation	1	1				20
Customer Discovery	0.8	0.8				20
Other experience with scaling an educational innovation	0.7	0.3 (n=14)	2.3 (n=3)	1.2 (n=9)	1 (n=7)	63
The Business Model Canvas	0.3	0.3				20

Note: Only T1 data available. Not all items were asked on all surveys, see last column for max number of potential responses. For the item "Other experience with scaling an educational innovation", the response rate is much lower, and is appropriately noted. For all other items, actual N is close to max N

Team Organization

Most (90%) of the teams started within their host academic institution (Table T26). One of the assumed indicators of progress in creating an enterprise in support of the ICL team's innovation is that there would be a migration to a new organizational structure. At T1, a quarter of the teams reported being in a new structure with 30% saying they expect to be in a new structure a year later. By T2 evidence of that shift is limited as 21 of the 26 teams responding (80%) said that they were still in the educational structure in which they started. Nine of those teams, however, still say they anticipated being in new structure a year hence (Table T27). When asked what structure they would like to operate in, the answers are decided mixed (Table T28).

Table T26: Activity Index and Current Organizational Structure

Q. In what organizational structure does your innovation reside?

	T1				T2			
	T1 Total	A	B	C	T2 Total	A	B	C
The educational institution in which it started	39	11	9	7	21	12	6	3
A for-profit, independent company	14	1	3	4	6	3	3	0
A new entity under the educational institution's umbrella	2	1	0	0	3	1	2	0
A new home under another organization/partner	4	1	2	1	0	0	0	0
A non-profit, independent	7	0	2	2	2	1	1	0
Other	4	1	1	1	5	2	2	1

Note: Teams could select multiple answers. T1 Max per selection N = 58; T2 Max per selection N = 31

Table T27: Activity Index and Future Organizational Status

Q. Do you anticipate operating in a different structure a year from now?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
Yes	17	5	4	5	9	2	6	1
No	38	8	10	7	20	10	7	3
Maybe	2	0	0	0	1	1	0	0

Note: T1 Max N = 58; T2 Max N = 31

Table T28: Activity Index and Desired Organizational Structure

Q. What organizational structure would you like to operate in?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
The educational institution in which it started	3	0	1	0	1	0	0	1
A for-profit, independent company	7	0	2	2	4	1	3	0
A new entity under the educational institution's umbrella	5	1	1	1	3	1	1	1
A new home under another organization/partner	3	1	1	1	3	0	2	1
A non-profit, independent company	3	3	0	0	2	1	0	1
Other	6	2	1	2	2	0	2	0

Note: Teams could select multiple responses. T1 Max per selection N = 17; T2 Max per selection N = 9

Team Innovation

Most teams at T1 describe their innovation as both a product and a service (69%). Those teams responding at T2 show little change to that description. Proportionally, however, those teams that demonstrate progress at T2 are more likely to be those with a service/program. This may be in part due to the pursuit of grants, which tend reward proposals that are more service and program oriented (Table T29).

Table T29: Activity Index and Innovation Description

Q. Which of the following describes your innovation?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
A product	6	0	1	2	3	2	1	0
A service/program	12	4	4	1	12	5	5	2
Both a product and a service	40	9	9	11	12	6	5	1

Note: T1 Max N = 61; T2 Max N = 31

When asked to describe their market, there is a balance between those saying K-12 and Higher Education at T1. By T2, the A/B Teams are more likely to be in K-12 than higher education (Table T30).

Table T30: Activity Index and Market

Q. Which of the following describes your market?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
Adult informal education	5	0	0	0	3	2	1	0
Higher education	29	4	6	9	14	4	7	3
Industry	8	0	2	1	3	0	3	0
K-12	29	9	6	4	19	10	6	3
Other	2	0	0	0	2	0	1	1

Note: Teams can select more than one market. T1 Max N = 61; T2 Max N = 31

Whether or not the innovation is said have protectable Intellectual Property does not appear to be associated with teams progressing. At T1, 48% of the teams responding said they had protectable IP. At T2, 35% of the A/B teams responding said they had had protectable IP (Table T31).

Table T31: Activity Index and IP

Q. Does your innovation have protectable IP?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
Yes	26	6	4	10	9	4	4	1
No	13	3	4	2	10	6	2	2
Not sure	15	4	5	1	7	3	4	0

Note: T1 Max N = 58; T2 Max N = 31

Customers

At T1, over two-thirds of the teams that were active said they had paying or non-paying customers. For many of these teams, the connection to concurrent funding provides the means for them to have customers. For the A/B teams at T2, 90% of these teams claim to have customers with roughly half of those customers being non-paying (Table T32).

Table T32: Activity Index and Customers

Q. Do you have customers who purchased or used the innovation?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
No	20	2	2	7	6	1	2	3
Non-paying customers being supported through one of our grants or other funds	17	6	4	2	11	7	4	0
Paying customers	12	4	1	3	7	3	4	0
Both paying and non-paying customers	6	0	4	1	5	2	3	0

Note: T1 Max N = 58; T2 Max N = 31

The evidence that teams developed new customers as a consequence of ICL is shown in Table T33. When asked how much of the purchasing/adoption can be attributed to participation in ICL, 6 of 9

responding Cohort 3 teams (T1) already were claiming an impact of ICL on developing these new customers. At T2 59% of the A/B teams that responded said attributed new purchasing or adoption to their participation in ICL.

Table T33: Activity Index and Usage Attributable to ICL

Q. Approximately how much of the purchasing/adoption can you attribute to your participation in ICL?

	T1				T2			
	T1 Total	**A**	**B**	**C**	**T2 Total**	**A**	**B**	**C**
None	4	0	1	0	1	0	1	0
A little bit	1	0	0	1	6	3	3	0
Moderate	7	1	1	1	6	4	2	0
All	5	0	2	1	4	3	1	0
Note: Only S16 and S17 data. T1 Max N = 17; T2 Max N = 23								

When funding history and customer history are combined (Table T34), Cohort 1 stands out as distinct from the other two cohorts at T1. The innovations were more likely to have been supported by funding and had either paying or non-paying customers. Comparing Cohorts 2 and 3 shows Cohort 2 with more funding but fewer established customers.

Table T34: Key Differences between Cohorts related to Funding/Customers

	Cohort 1	**Cohort 2**	**Cohort 3**
Innovation funded at T1 (% Teams saying yes)	75%	68%	45%
% Saying at T1 they had funds other than prior grant	67%	42%	20%
Percent of teams at T1 with one or more saying personally funded	67%	68%	55%
% saying at T1 they have paying or non-paying customers	75%	39%	50%
% with Pre-ICL funding (NSF Award Search)	83%	89%	67%
% with Pre-ICL funding >$1,000,000	46%	26%	33%

5.5 Obstacles

The top challenge that teams faced were fairly consistent and persistent between T1 and T2 – securing key financial resources. The next three obstacles, securing key human resources (i.e. time, expertise), lack of personal time and determining viable revenue streams, also remained widespread and persistent (Table T35). Items not seen as obstacles were lack of evidence of educational efficacy of the intervention and having a value proposition compelling to customers. For the A and B teams of cohorts 1 and 2 at T2 new obstacles emerged associated with their home institution in terms of financial and political support.

Table T35: Activity Index and Obstacles

Q. Below is a list of obstacles. Please indicate how challenging each were, if encountered by your innovation (0 = Not at all; 4 = Insurmountable).

	T1				T2			
	Avg. T1 (N=61)	**A (n=13)**	**B (n=14)**	**C (n=15)**	**Avg. T2 (N=30)**	**A (n=13)**	**B (n=14)**	**C (n=3)**
Securing key financial resources	**2.6**	**3.0**	**2.3**	**2.1**	**2.2**	**2.2**	**2.4**	1.7
Securing key human resources (i.e. time, expertise)	2.0	2.3	2.1	1.8	1.9	2.1	2.0	0.7
Lack of personal time	1.9	2.7	2.1	1.1	1.9	2.0	2.1	1.0
Determining viable revenue streams	1.9	2.3	1.6	1.5	1.9	2.1	1.9	0.7
The work / cost of supporting the customer relationships	1.8	1.8	1.8	1.7	1.8	1.9	2.0	0.7
Determining a viable cost structure	1.8	2.3	1.4	1.6	1.6	1.9	1.4	1.0
Establishing key partnerships	1.6	1.8	1.5	1.4	1.7	1.8	1.8	0.7
Identifying the appropriate channels to market	1.6	1.7	1.5	1.6	1.7	1.8	1.8	1.3
Lack of financial support from our institution	1.5	1.0	1.3	1.7	1.5	1.3	2.0	0.3
Other institutional barriers	1.4	1.3	0.8	1.8	1.5	1.5	1.7	1.0
Focusing on customer segments	1.3	1.6	1.3	1.3	1.3	1.3	1.4	0.7
The innovation would take too long to scale	1.4	1.6	1.2	1.3	1.1	1.5	1.1	0.0
Problems with the innovation itself	1.0	0.9	1.1	1.0	1.1	1.3	0.9	1.0
Lack of political support from our institution	1.0	0.7	0.8	1.5	0.8	0.8	0.9	0.3
Team challenges	0.9	0.9	0.6	1.0	1.1	1.2	1.4	0.0
Value propositions were not compelling to customers	0.9	1.0	0.6	0.8	0.8	0.9	0.8	0.7
Lack of evidence of the educational efficacy of the innovation	0.8	0.9	1.1	0.5	0.8	1.2	0.6	0.3

Note: T1 Max N = 61; T2 Max N = 31. For each item, Ns substantially less than the max N are noted. Highest reported N across items for each A,B,C category reported in respective columns.
Obstacles that were the most challenging (2 or above) are highlighted for easy reference.

Stage of Development

One means of determining the stage of ICL Teams was to ask them to describe themselves on a scale that stretches from early concept to scaling (Table T36). This analysis is presented only for those teams active at the time of the Spring 2017 survey. For Cohort 3 (T1) most teams (78%) say they have conducted customer discovery (the bulk of the effort associated with the ICL experience) and almost half (44%) say they have competed the Business Model Canvas. Almost 25% of the Cohort 3 teams are in the process of implementing their model and 39% say they are focusing on scaling the innovation. For the active teams in Cohorts 1 and 2 and T2, a higher percentage are implementing their model and/or

focusing on scaling. Given the iterative nature of this process, it is also interesting to note that many are still engaged in Customer Discovery (some would argue customer discovery never ends). This also is one question we see the largest difference between the A and B teams with the A teams more likely to be at later phases of their innovation development than the B teams.

Table T36: Activity Index and Development of the Innovation

Q. Please mark the descriptions below that best describe your innovation's development right now[10]

Note: Only S17 data; Teams can select multiple items.	% of Active Teams			
	T1 (Cohort 3)	**T2 (Cohorts 2&3)**	**T2 A**	**T2 B**
	n=18	n=31	n=13	n=14
Our team has a concept or possibly a Minimum Viable Product. We have not conducted much, if any, customer discovery	11%	0%	0%	0%
Our team has a product, program, or service that has been successfully implemented. We have not conducted much, if any customer discovery	22%	6%	8%	7%
Customer Discovery: Our team has conducted extensive customer discovery, identified value propositions that align with customers	78%	58%	69%	57%
Sounding the Business Model: Our team has completed the Business Model Canvas (or a business model) and has tested or are testing	44%	39%	38%	43%
Gathering Evidence (Sales): Having sounded our model with experts, perhaps making adjustments, we are now implementing it	17%	6%	8%	0%
Gathering Evidence (Grants): Having sounded our model with experts, perhaps making adjustments, we are now implementing it	6%	29%	38%	21%
Scaling: Having successfully demonstrated the efficacy of our model, our team now focuses on scaling the innovation	39%	48%	69%	43%
Note: T1 Max per selection N = 18; T2 Max per selection N = 31.				

3.7 CONCLUSION

Capturing a comprehensive story about the ICL teams is challenging. It starts with differing initial conditions associated with the nature of the innovation in terms of what was the assumed market, the level of investment that had preceded, the experience of the team and perhaps what was most challenging to capture, the intent of the ICL team itself vis a vis how they defined successfully scaling and sustaining their innovation.

There are also differences in what happened during the ICL experience and in the period of team activity leading to the first survey (T1). The preceding Tables demonstrate the importance of having the time available to advance their innovation after the ICL training. One key factor may be that Cohort 1 had the opportunity to follow up on their ICL experience during the subsequent summer prior to the T1 survey. Cohorts 2 and 3, having gone through ICL during the summer did not have this same opportunity prior to

[10] Development stages and types adapted from: Errol Arkilic, M34 Capital (2016). Evidence-Based Entrepreneurship: What's Next. Presentation at I-Corps(TM) L, Winter 2016.

their T1 surveys. Given the prevalence of time being an obstacle, this may be why we saw more progress at T1 for Cohort 1 teams than the others.

The ICL experience is time intensive and for those teams participating in the summer, it appears that finding the time to advance the innovation is a particular challenge once the Fall semester begins. Having significant concurrent funding from a grant appears to be an important factor in allowing the team, and perhaps particularly the EL stay active in moving the innovation forward.

There is also wide variation in the nature of customers, the market being addressed and the characteristics of the innovation itself. These all suggest that there are a set of variable associated with the ecosystem in which the team is trying to succeed that the data presented here only touches upon.

Finally, for those teams that continue to progress, the intent of the teams to scale and sustain differs in that there are teams that obviously are striving to grow through continued and new federal grants. There also are others that show evidence of moving into more entrepreneurial space. We see evidence of both in the most advanced teams that were identified at T2.

4. INSTITUTIONS

As part of the surveys, respondents were asked to reflect on how their institutions have changed as a result of ICL by responding to a battery of questions. Table I1 presents the areas of impact as perceived by the PI, the EL and as a team. The ELs and PIs have slightly different perspectives, likely based on their familiarity with the politics of the institution. Overall, most teams reporting say that faculty have adopted new or different processes, and that the institution has had to address Intellectual Property (IP) associated with the project in a new or different way than in the past. Finally, teams also report that the reputation of the institution has improved.

Table I1: 2017: ICL Impact on the institutions.

Q. We are interested in the effects of I-Corps-L on participants' organizations. In this question, we are interested in ways scaling and sustaining your innovation has impacted the infrastructure, mission, and/or operations at your institution. Have any of the following happened? [Check all that apply]

	EL	PI	Teams
Faculty have adopted new or different practices	5	11	15
My institution has had to address IP associated with this project differently (or newly) than in the past	6	7	12
The reputation of my institution has improved	1	10	11
Other	5	2	7
My institution has had to account for revenue of this type, which is new or different than in the past	2	4	5
My institution has had to address employment issues that are new or different than in the past	2	2	3
The number of industry partners my institution has changed	2	1	3
16 of the 45 EL survey takers and 21 of 35 PI survey takers responded to this question.			

On previous iterations of the survey participants explained their answers. When discussing the impact on faculty, most report the integration of entrepreneurship or an entrepreneurial mindset being brought into the classroom. For example:

> *I approach my current role as a faculty member with an entirely new perspective. I infuse entrepreneurial mindset and learning into my teaching; I approach fundamental research problems with a translational research application and consider what sustainable scaling would look like from the beginning; and I am dedicated to bringing ICL-like experiences for students and faculty at my university*.

IP is another issue that institutions have had to face. Many of the ICL participants come from small schools that may not have had to address IP, which is more common in the large research universities. Comments suggest that challenges include ownership, when to file a patent, and how to accommodate royalties.

The impact of ICL teams seeking to scale and/or sustain on the home institutions, and the institutional context's impact on their ability to scale and/or sustain is still not well understood. Further study is recommended to understand how the institutions affect ICL teams and their success, and how the ICL teams affect the institutions.

5. INDIVIDUALS

5.1 OVERVIEW

The ICL teams are made up of a Principal Investigator (PI) and an Entrepreneurial Lead (EL), although some teams had more than one PI or EL. Each team also included a mentor[11]. This section details the qualities of the PIs and ELs and the impact on their professions.

Typically, the PI is a researcher with a current or previous NSF award who has significant knowledge of the team project and is responsible for overall grant management. The PI holds the intellectual capital underlying the innovation and supports the EL in developing the idea and moving it forward. The EL, envisioned as a post-doc or graduate student who leads the effort to move the project forward, is tasked with a deep commitment to investigate the landscape surrounding the innovation. The EL is the primary interface with the ICL teaching team and is the only one allowed to speak at presentations. ELs typically take the lead with customer interviews.

The surveys were designed to answer three core questions from the individual participant's perspective:

1. What are the professional experiences and motivations of the participants in ICL?
2. What was the impact of ICL on the individuals?
3. What was their satisfaction and view of ICL?

Data were collected twice for Cohorts 1 and 2 and once for Cohort 3. Unless noted, data presented in this report are taken from the most recent time point available. As a caveat, the readers should note that at the time of the 2017 spring survey, for which much of the individual data was taken, participants were anywhere from 7 months to two years away from their training experience.

The total number of responses to the Spring 2017 survey is 92, with 48 ELs across the cohorts and 44 PIs. However, since 12 of these respondents only completed the Spring 2017 "Short" survey, the n for most of the items presented in this chapter is 80, with 35 PIs and 45 ELs. A more detailed breakdown of these response rates is presented in Table A1 in chapter 2.

Most teams have a unique PI and EL, allowing for the possibility to "match" responses in T2 to their respective responses in T1, generating a genuine longitudinal dataset to examine individuals' changing characteristics, as well as their attitudes of ICL overtime. However, some teams had multiple PIs or ELs, excluding the possibility of guaranteeing correct correspondence of certain responses, and others did not answer both sets of surveys (Fall 15 and Spring 17 for Cohort 1, and Spring 16 and Spring 17 for Cohort 2). This limits the size of this longitudinal dataset to N = 44, with equal representation from each cohort. There are 23 ELs and 21 PIs represented. Note that cohorts are aggregated to the time-level in this analysis, and since there are no T2 observations for cohort 3, these data are excluded.

[11] Mentors are discussed in the subsequent chapter titled "Mentors."

Information about the current status of PIs and ELs is drawn primarily from the Spring 2017 survey data, which includes all three cohorts. The second question is answered primarily drawing upon the longitudinal, "matched" data to understand change. Finally, "satisfaction" draws again from the Spring 2017 survey data.

5.2 About the PIs and ELs

Current Employment and Motivation

The PIs and ELs are primarily based in institutions of higher education. PIs are primarily faculty, and ELs are program professionals, faculty members and graduate students (Table P1). The team members who are in non-academic roles and entrepreneurs are more likely to be in the EL role. There are only six teams that are not based in an academic setting.

Table P1: Team member primary employment.

Q. Which of the following describes your primary employment?

Spring 2017 Data	All		Cohort 1		Cohort 2		Cohort 3	
	EL	PI	EL	PI	EL	PI	EL	PI
University Administrator	2	2	1	2	1	0	0	0
Faculty member	6	26	2	7	0	9	4	10
Program professional (program director, manager, etc.)	9	1	5	1	1	0	3	0
Graduate student	5	0	3	0	1	0	1	0
Postdoc	2	0	0	0	1	0	1	0
K-12 professional	1	1	0	0	0	1	1	0
Non-academic professional	10	2	2	1	5	1	3	0
Entrepreneur	8	2	3	0	0	0	5	2
Other:	9	2	3	0	2	1	4	1

Table P2 shows that by the 2017 survey, about a third of the participants are funded through soft money. ELs are more likely to be funded through soft money, at 44% with only about a quarter of PIs are funded through soft money. Those that are funded on soft money are typically program professionals who although are hired to work on specific grant opportunities, are often able to build a career based on soft funding that results in a stable career.

Table P2: Team member funding source

Q. Is 50% or more of your position primarily funded through soft money (grants lasting 1-5 years)

Spring 2017 Data	**EL+PI**	**%**	**EL**	**PI**
Yes	29	36%	20	9
No	51	64%	25	26

The team members are spending significant time directly developing or implementing the innovation, though not as much as conducting STEM related research, which suggests that although they are

working on the innovations, they're still spending most of their time on the responsibilities associated with their primary employment (Table P3). There was not much difference between how the PIs and ELs currently spend their time, with the exception of teaching for which the PIs were spending more time.

Table P3: Distribution of time

Q. Approximately how much of your time is associated with each of the following?							
Spring 2017 Data			*Hours per week*				
	n	Mean (corresponds to segment of hours worked)	0 (0)	up to 10 (1)	11-20 (2)	21-32 (3)	More than 32 (4)
Directly developing or implementing our innovation	80	1.2	20	41	10	4	5
Science, Technology, Engineering or Math research	72	1.5	19	26	10	8	9
Delivery/Support of Science, Technology, Engineering or Math educational programs	74	1.1	20	33	13	7	1
Administrative responsibilities	73	1.1	18	38	13	3	1
Science, Technology, Engineering or Math teaching	73	1.0	25	34	8	2	4

Of the 31 PIs and 26 ELs that are still involved in the innovation in spring 2017, 40% are working without funding, and another 23% with original funding (either a prior grant that developed the ICL innovation or the ICL grant funding). There are some individuals who are supported by new funding, primarily going to the ELs (Table P4).

Table P4: Current funding

Q. Are you currently personally funded to work on the innovation?				
Spring 2017 Data	**PI**	**EL**	**EL+PI**	**% (n=57)**
Yes, I still have the original funding	6	7	13	23%
Yes, with new funding	8	4	12	21%
Yes, with original and new funding	3	6	9	16%
No	14	9	23	40%

Most of the team members that have gone through ICL are looking to scale and sustain their innovation within the context of their own professions; they are not looking to start a new company. Table P5 presents the number of ELs and PIs identifying with each motivation type, and the percentage of the population that identifies as such.

Table P5: Motivation type

Q. Below are 3 types of I-Corps-L participants. Which best describes you? (select one)				
Spring 2017 Data	**EL**	**PI**	**EL+ PI**	**% of EL&PI** (n=79)
Type 1: Want to be an entrepreneur and succeed in the startup world.	12	2	14	18%
Type 2: Want to scale and sustain my innovation within the context of my current profession. Not primarily interested in starting a company.	19	21	40	50%
Type 3: Want to scale and sustain my innovation AND succeed in both the startup world and in my current profession. (If you are an entrepreneur, select Type 1.)	13	12	25	32%

Prior Experience

PIs and ELs came to the ICL with limited experience in business, law and commercialization. Table P6 presents the prior knowledge of PIs and ELs respectively. PIs have slightly more experience with securing IP.

Table P6: PI and EL prior knowledge and experience

Q. Prior to I-Corps-L, how would you rate where you were with the following?		
Scale: none=0; a little= 1; a moderate amount=2; a lot=3 *Spring 2017 Data*	**EL (n=17)**	**PI (n=12)**
General business knowledge relevant to commercialization	1.2	1.1
General legal knowledge relevant to commercialization	1.0	1.0
Other experience with scaling an educational innovation	0.9	1.1
Commercializing an innovation	0.8	1.0
Securing IP	0.7	1.0

5.3 IMPACT ON INDIVIDUALS

Changes in employment

Out of the total number of respondents, 16 (about 37%) had a change in their employment between the first and second survey time points (T1 and T2). Of the 16 people who report a change in their employment, 7 of them are graduate students, whose employment change is expected. This suggests that only a few people are changing their careers as a consequence of ICL. These data (Table P7) show discrete counts of T2 employment by T1 employment. The first column of Table P7 represents the position of each respondent at T1, and column 2 presents the total count of each position. The remaining columns show the number of respondents who changed from one position to another in T2. For example, there were 17 faculty members at the first time point, but at T2, 11 still identify as faculty members with one having moved to identifying as a non-academic professional and one as a university administrator (4 did not report at T2 position). The blue cells, running along the diagonal of the Table

P7, represent the line of "No change" (e.g., the number of faculty members in T1 who remained faculty members in T2).

Table P7: Changes in employment by T2 role

T2 Role→ T1 Role ↓	**Role Total**	**University Administrator**	**Faculty Member**	**Program Professional**	**Graduate Student**	**K-12 Professional**	**Non-academic Professional**	**Entrepreneur**	**Other**	**Not reported**
Longitudinally Matched Data										
University Administrator	1	0	0	0	0	0	0	0	0	1
Faculty Member	17	1	11	0	0	0	1	0	0	4
Program Professional	8	0	0	5	0	0	1	1	1	0
Graduate Student	9	0	2	0	2	0	5	0	0	0
K-12 Professional	0	0	0	0	0	0	0	0	0	0
Non-academic Professional	3	0	0	0	0	0	1	1	1	0
Entrepreneur	0	0	0	0	0	0	0	0	0	0
Other	6	1	0	0	0	1	0	0	4	0
Not reported	0	0	0	0	0	0	0	0	0	0

In these data, faculty members represented the largest number of employment type in T1, and also had little outflow in T2. Several did not report their employment in T2, while the majority remained in their position. For graduate students, the next largest category by T1 employment, there was more variation in their T2 employment, which is expected given their status. Most became Non-academic professionals, and others became faculty members. Two respondents also became entrepreneurs by T2, even though there were none in T1.

Respondents were asked about the influence of ICL on the change (or lack of change) in their employment status. These responses are displayed below in Table P8, where the first two columns indicate the overall results from this question, and the second two columns present these data only for those who did indicate a change in their employment based on the previous item.

Table P8: Change in employment because of ICL

Q. Has this position changed because of ICL?				
Spring 2017 Data	n	% of Total	Number change	% change
No	32	82%	11	69%
Yes, because I am now engaged in entrepreneurial education and/or research	1	3%	1	6%
Yes, because of working on the innovation	2	5%	1	6%
Yes, I-Corps-L contributed to my change in position but was not wholly responsible	4	10%	3	19%

As can be seen, the vast majority (82%) indicated that they did not change their position because of ICL, though seven individuals report that they have moved into new positions in part or wholly because of ICL, all of them ELs. Four of these ELs are now non-academic professionals and one an entrepreneur. Two are program directors and one is a faculty member. For these participants, ICL was profoundly impactful on their careers, as seen in the following comments:

- *It gave me the security to lead the implementation of the program. Customer discovery is now a natural part of each program I work with. (Program Manager)*
- *I now work at a non-profit that uses a lot of these types of funding channels. (Non-academic professional)*
- *The importance of customer discovery and making a product that people want, not just what you think they want. This have impacted my teaching as well. (Faculty member)*
- *The training at ICL was really useful, empowering and valuable. It gave a boost to my self-confidence to pursue my career goals and also gave real sense of being an entrepreneur. I got a great job in a big automotive company and plan to use the lean startup methodology to pursue some ideas and start my own company in the near future. (Non-academic professional)*

Changes in funding status

Out of the participants who were funded by soft money in T1 about 50% maintained this status in T2, while the other 50% lost this status (Table P9). This does not mean that they are no longer funded, as they could have found alternative means to continue their work. About 30% (6) of those who did not have soft funding in T1 had gained it in T2, which could be reflective of ICL participants using their training to win more substantial grants or secure other investments.

Table P9: Funding Source

Q. Is 50% or more of your position funded through soft grants?		
Longitudinally Matched Data	**T2**	
T1	Yes	No
Yes	9	9
No	6	15

Table P10 presents change in funding, be it new or old funding sources, or a combination, between T1 and T2 in a similar manner to Table P8, where the first two columns present T1 status and totals, and the remaining show how these statuses distribute across time, again with the blue diagonal representing no change.

Table P10: Current funding

Are you currently personally funded to work on the innovation?

Longitudinally Matched Data		By T2 Response			
T1	T1 Total	No	Yes, with Original Funding	Yes, with New Funding	Yes, with Original and New Funding
No	22	7	1	3	0
Yes, with Original Funding	15	3	4	1	3
Yes, with New Funding	3	1	0	2	0
Yes, with Original and New Funding	4	0	1	2	0
Note: Non-response answers in T2 are not presented					

About half of the respondents who indicated "No" in T1 and responded in T2 reported being personally funded with new funds. Two of those who had new funding in T1 continued with new funding in T2, and half of those with both in T1 transitioned to working just with new funding in T2. Only one team transitioned from just the original funding to new funding between T1 and T2.

Changes in work approach

As a result of participation in ICL, participants changed how they approach developing and/or implementing educational products, programs and services (Table P11). This was true for both ELs and PIs; this was also particularly true for teams that reported high levels of success in T2 as indicated by the Activity Index.

Table P11: Impact of ICL on careers

Q. To what extent has participation in I-Corps-L influenced your approach to the following?

Scale: 0=none; 1= a little; 2= a moderate amount; 3= a lot; Spring 2017 Data								
	N	**PI & EL**	**PI (n= 34)**	**EL (n=40)**	**A (n = 21)**	**B (n = 11)**	**C (n = 15)**	**Null (n = 24)**
Developing/implementing education products, programs or services	74	2.2	2.2	2.1	2.5	2.1	1.7	2.2
My career	73	1.9	1.9	1.9	2.1	1.7	1.9	1.8
Mentoring	74	1.7	1.7	1.7	1.8	1.4	1.6	1.8
Research	73	1.6	1.6	1.7	1.9	1.3	1.9	1.4
Teaching	73	1.5	1.5	1.4	1.7	1.1	1.4	1.4

Participants report that the ICL program has changed the way they think about innovation and entrepreneurship, which has impacted how they work, for many this meant instilling an entrepreneurial mindset. Several are teaching courses that now integrate elements of entrepreneurship including the BMC and customer discovery. Others are pursuing startup businesses. In open end responses, participants report that the impact on their career include:

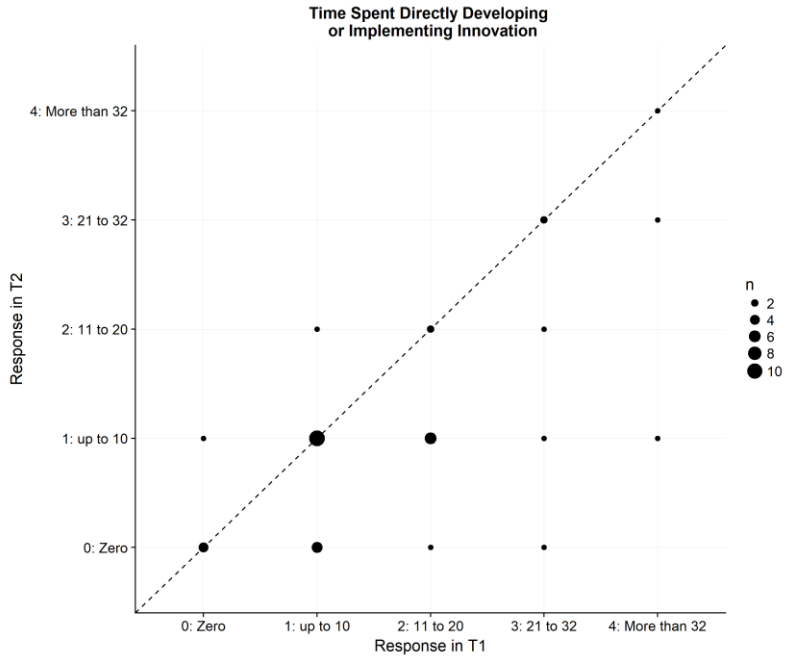
- *I have begun to see my teaching and research as opportunities to encourage entrepreneurship in my students, and I am more apt to actively think of ways in which the work that I do might solve a problem for others, which they might be willing to pay me for. Given the persistent socio-economic gaps that exists for the students that I serve, it is increasingly important that we impress upon them the importance of innovation and entrepreneurship as a means of economic empowerment. (Program Professional)*
- *The training at ICL was really useful, empowering and valuable. It gave a boost to my self-confidence to pursue my career goals and also gave real sense of being an entrepreneur. I got a great job in a big automotive company and plan to use the lean startup methodology to pursue some ideas and start my own company in the near future. (Non-academic professional)*
- *I become aware about the opportunities for the commercialization of the educational product that we developed and how it would positively affect the students' education. (Faculty member)*
- *I have been afforded state, regional, and international recognition for my work in the program and my affiliation with science teachers in at least 16 school districts in the state. In addition, I have been invited to be a keynote speaker at an international science and technology education conference on the topic: Providing Quality Science Education: The Foundation for Creativity, Innovation and Sustainable Development. (Faculty member)*
- *I'm now leading the development of a commercialization track within a Master of Science (MS) in Clinical Research degree program in our university. I believe I got the position in part because of my experiences (x2!) in the I-Corps program. (Faculty member)*
- *I am considering leaving my faculty position and working for the program full-time. (Faculty member)*

Overall, when it comes to actual career changes, ICL appears to have minimal to no effect on participants' career paths – at least when it comes to changes. Many of the positions discussed are flexible in terms of the precise work that is done on a day-to-day basis, so it appears that within-career changes are where ICL is most impactful.

Time spent on the Innovation

Overtime, individuals spent less time on their innovations. Figure P1 below displays the time each individual spends on directly developing or implementing their innovation, with T1 on the x- axis and T2 on the y-axis. The size of each point corresponds to the number of observations with identical T1/T2 combinations. Here, the 45-degree line (dotted) represents no change. The general change in time spent on each item can be easily assessed by examining the number of observations below or above this line, indicating a decrease or increase in time spent, respectively. Visually, it appears that about half of the individuals reported spending the same amount of time on their innovation. However, many individuals also reported spending relatively less time (personally speaking) on their innovation, indicated by the large number of responses below the 45-degree line.

Figure P1: Time spent directly developing or implementing the innovation



5.5 Participant Satisfaction and View of ICL

PIs and ELs were very satisfied with the program, having embraced the ICL processes and tools and having developed an entrepreneurial mindset that has transferred to their teaching and other job components. ELs have particularly embraced the customer discovery process and PIs have changed the way they approach presenting innovations. Overall participants report that the gains from ICL were well worth the time spent in the program (Table P13). PIs and ELs didn't vary much in how they responded. In particular, the participation in the program increased the determination to continue pursuing scaling and sustaining their innovations. Those from the more successful "A" teams, however, were more likely to see having gone through ICL as a team as having a direct impact on their determination to continue.

Table P12: Participant Satisfaction

Q. Please indicate your level of agreement with each of the following						
Scale: 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly Agree *Spring 2017 Data*						
	PI & EL (n=73)	**PI (n=33)**	**EL (n=40)**	**A (n = 46)**	**B (n=39)**	**C (n=44)**
Overall the gains from I-Corps-l were worth the time devoted to it	4.3	4.2	4.3	4.5	4.2	4.2
The experience of spending an intense amount of time as a team increased our team's determination to continue	3.8	4.1	3.5	4.1	3.7	3.3
The people I met from other I-Corps-L teams have proven to be valuable contacts	3.3	3.4	3.2	3.5	3.2	3.1
The trainers and experts from I-Corps-L have proven to be valuable professional contacts	3.2	3.3	3.2	3.3	3.1	3.3

Overall, participants valued the ICL experience, as evident by their comments:

- *Fantastic experience. I now approach daily situations with an entrepreneurial mindset. (Graduate Student)*
- *Due to I corps L I go into everything with a different mindset. I look for results and see what works and what doesn't work and adjust what I do from there. (Non-academic professional)*
- *Provided opportunities to interact with graduate programs, faculty, and students across the country, as well as with internal and external partners. Gained insights and ideas for additional programming. (Non-academic professional)*
- *I am at the apex of a long career with many prior STEM research/education innovations. I-Corps-L changed my approach through entrepreneurship, partnering more closing with the corporate sector and being able to overcome hurdles to scaling the innovation. These are all important to my career development. (Faculty member)*
- *It was a very valuable experience but came with a high opportunity cost. I do not yet know what the long-term return on the investment of that time will be.*
- *This was one of the greatest professional development opportunities. I am very grateful to have been a part of this program. (Program Professional)*
- *Although our product ended up not being viable, I continue to extrapolate learning from the I-Corps-L experience to other aspects of professional work. Teaching academics (and others!) to apply a business model to sustain innovations is key to getting off soft-money, and for NSF to be fully successful in ensuring that project sustainability is integrated into funded work. (Other)*

5.6 Conclusion

The ICL program had a positive impact on individuals and the participants were favorable about the program. The effects of ICL however were seen mostly through participants developing entrepreneurial mindsets and not in a new career path pursuing commercialization of their innovations.

The participants in ICL often have a STEM research background and have moved into education, often via grant funding from NSF. Most faculty are self-described as inexperienced in business or law, particularly as it relates to commercialization of a business venture. The participants are not looking to move out of their current professions, rather they turn to ICL looking to scale and/or sustain their educational innovations.

This model is different from the canonical I-Corps™ program in which the model is typically that of a research faculty member commercializing an innovation from their discipline. In ICL, the ELs are likely to be practitioners and sustaining and/or scaling is part of their current professional responsibilities and/or ambitions, which may not be the case in canonical I-Corps™. This is further evidenced by the finding that time spent on the ICL innovation seems to decrease over time, likely due to lack of funding or as other priorities emerge.

Changes in participants longitudinally have been modest. Professionally, not much has changed in terms of their career trajectory; rather the entrepreneurial mindset they developed through the training has influenced their approaches to teaching, and other daily responsibilities.

6. MENTORS

6.1 OVERVIEW

The ICL Mentor's role is "to help the team discover and utilize their own social network, to teach the team how to get meetings, to teach the team how to listen and not sell, to teach the team how to think past the technology and toward the business model, to provide specific and actionable advice, to teach the team how to iterate and pivot," as presented to mentors during the cohort's opening workshop. The slides continue to explain that the mentor role is NOT "to do ALL of the customer discovery, to sell when you should be listening, to innovate the business model yourself." They encourage mentors to "post at least once a week, talk to the PI/EL at least once a week, review weekly presentations before they present, and to act as an extension of the teaching team.[12]"

Each team included a mentor who was typically chosen by the PI and EL, but in a few circumstances a connection between teams and a mentor was facilitated by NSF. Mentors attended all course sessions and may have participated in the customer discovery interviews and were ineligible for financial support through the ICL grant.

In the spring of 2017 mentors were asked to complete an on-line survey about their experience in ICL. The Mentor survey received 38 responses, for a response rate of 62%. This was complemented by a module administered to the PIs and ELs in the Spring 17 survey, where they were asked similar questions to garner their perspective on the mentors' role and value. All data in this section comes from these two surveys.

Given the response rate, it is possible there is some response bias in the degree of mentor involvement, with those still involved with the team more likely to respond to the survey. There appears to be minimal bias, however, when looking at the responding mentors and the Activity level of their teams and innovations.[13]

The mentor survey was designed to answer four questions:

1. What are the characteristics of the mentors?
2. What is the value added to the teams and innovations by having mentors on the team?
3. What was the personal benefit of participation in ICL to the mentors?
4. What is the mentors' view of ICL?

The data presented below are reflective of the mentor's experience, not the success of the team and innovation.

[12] I-Corps-L mentor course orientation slides
[13] See the methods section (Figure A7) for the definition of the Activity Index variable.

6.2 About the Mentors

Most Mentors came to the ICL with a working relationship with the team, with 61% having worked with the team on the innovation in the six months prior to ICL. Most of the mentors are either entrepreneurs and/or investors (29%) or other non-academic professionals (26%), though a significant percentage are affiliated with an institution of higher education (45%) (Table M1).

Table M1: Mentor employment

Q. Which of the following describes your primary employment?

	%	# (N=38)
Entrepreneur / investor	29%	11
Non-Academic professional	26%	10
Faculty	21%	8
Program professional (program director, manager, etc.) based in Higher Ed setting	16%	6
University administrator	5%	2
K-12 Educator or professional	3%	1
Other	13%	5

Mentors were asked to describe themselves, comparable to what was asked of PIs and ELs, according to three types:

- Type 1: Want to be an entrepreneur and succeed in the startup world.
- Type 2: Want to scale and sustain my innovation within the context of my current profession. Not primarily interested in starting a company.
- Type 3: Want to scale and sustain my innovation AND succeed in both the startup world and in my current profession.

These motivation types are important for understanding the intentions and qualities of the mentors. Most mentors report that they are *Type 2 they want to sustain and scale their innovations within the context of their current professions; they are not primarily interested in starting a company* (Table M2). The mentors of the Cohort 1 were more variable in their motivation types, with an even split of those wanting to be entrepreneurs in the startup world and those wanting to stay in their current profession. By Cohort 3, however, there was a drift towards mentors with limited business/innovation experience, and mentors reported they want to stay in their current profession.

It seems that mentors answered this question for who they currently are, rather than an aspiration to change (as it is worded), which is reasonable given the mentors' role on the team. The experience that mentors bring to the teams confirms this assumption, with 1/3 describing market experience, 10 describe their experiences in academia, 2 are venture capitalists, 4 have prior IC experience and 2 have government experience. Those individuals that identify as entrepreneurs already were instructed to select "Type 1" which explains the low number of mentors responding as Type 3.

Table M2: Mentor type

Q. Below are 3 types of I-Corps-L participants. Which best describes you? (select one)

	All Mentors		Cohort 1 (n=15)	Cohort 2 (n=10)	Cohort 3 (n=13)
	%	#			
Type 1: Want to be an entrepreneur and succeed in the startup world.	34%	13	50%	50%	23%
Type 2: Want to scale and sustain my innovation within the context of my current profession. Not primarily interested in starting a company.	53%	20	47%	40%	69%
Type 3: Want to scale and sustain my innovation AND succeed in both the startup world and in my current profession. (If you are an entrepreneur, select Type 1.)	13%	5	*Too small of a number of responses to include in analysis*		

Given that over 45% of mentors are in a higher education setting overall, and 65% of Type 2 mentors are in educational settings, it is reasonable that they are not seeking to leave a secure position; however, it is unclear how well their current professions and entrepreneurial aspirations align with NSF's expectations of mentors. For example, as a group, the mentors have a moderate amount of experience with general business knowledge relevant to commercialization, customer discover and sustaining and scaling an innovation. They lack experience scaling innovations in the educational ecosystem (Table M3).

Table M3: Mentors' prior experience

Q. Prior to I-Corps-L, how much experience did you have with the following processes?

	n	Mean	None (0)	A little (1)	A moderate amount (2)	A lot (3)
General business knowledge as relevant to commercialization	38	2.2	4	5	9	20
Customer Discovery	38	2.1	7	4	5	22
Commercializing an innovation	38	2.1	5	6	9	18
Scaling and sustaining an innovation	38	2.0	5	6	12	15
Securing IP	38	1.7	8	8	10	12
General legal knowledge as relevant to commercialization	38	1.7	5	10	16	7
Scaling and sustaining an educational innovation	37	1.5	8	9	13	7
Familiarity with the ecosystem in which an educational innovation scales and sustains	37	1.5	8	11	9	9
The Business Model Canvas	38	1.3	15	7	5	11
Other experience with scaling an educational innovation: [describe]	32	1.1	10	13	6	3

Though the mentors' prior experience varied, it was overall more than the PIs and ELs brought to the course (Table M4) suggesting that the mentors had the potential to be important assets to the teams.

Table M4: Prior experience by team member type

Q. Prior to I-Corps-L, how much experience did you have with the following processes?			
Scale: 0= none; 1= a little; 2= a moderate amount; 3- a lot	**Mentor (=38)**	**PI (n=12)**	**EL (n=17)**
General business knowledge as relevant to commercialization	2.2	0.9	0.8
Customer Discovery	2.1	0.8	1.0
Commercializing an innovation	2.1	0.8	0.7
Scaling and sustaining an innovation	2.0	0.9	1.0
Securing IP	1.7	0.5	0.5
General legal knowledge as relevant to commercialization	1.7	0.8	0.8
Scaling and sustaining an educational innovation	1.5	1.1	1.3
Familiarity with the ecosystem in which an educational innovation scales and sustains	1.5	1.1	1.4
The Business Model Canvas	1.3	0.2	0.2
Other experience with scaling an educational innovation	1.1	0.2	0.6

When looking at employment type by entrepreneurial type, we find, unsurprisingly, that most of the Type 2 mentors are also in education. Those that are type 1 are typically an entrepreneur or investor or other nonacademic professional (Table M5) and several are in executive level positions and/or at startups.

Table M5: Mentor type by profession

	All Mentors		**Type 1**	**Type 2**	**Type 3**
	%	**#**			
Entrepreneur / investor	29%	11	9	1	1
Non-Academic professional	26%	10	1	6	3
Faculty	21%	8	1	7	0
Program professional (program director, manager, etc.) based in Higher Ed setting	16%	6	2	3	1
University administrator	5%	2		2	
K-12 Educator or professional	3%	1		1	
Other	13%	5	1	3	1

Mentors were asked what facets of their prior experience and training best prepared them for the role. Common themes were:

- Prior market experience
- Prior experience in academia
- Prior I-Corps Experience
- Prior experience as a venture capitalist (Tech based)
- Prior government experience

Examples of mentor explanations for how they were prepared include:

- *I have been in commercialization for over 20 years with a focus on product development and customer discovery, so I felt very prepared to assist my team in all the business aspects. (Program Professional)*
- *I taught a course related to new product development at a plastics company. My field experience was limited to the research side of things rather than the marketing side. (Non-Academic Professional)*
- *My prior experience as an entrepreneur and then high-level executive in a large business provided multiple perspectives to the [Name] team to help think through the process of commercializing their product. Both the initial start-up phase of a business and the ultimate running and growing a real business were not skills anyone else on the team possessed and I believe they were useful in defining how to take the product to market (Entrepreneur/Investor)*
- *I am a faculty member. I hold nine US patents, five are licensed so I have some relevant experience as an entrepreneur (Faculty)*
- *We run an I-Corps site, so our team had experience in delivering content; we gained additional experience by participating as a team in the national program. (Program Professional)*

Expectations of role prior to the course

Just over 60% of mentors were involved with the ICL team in the six months prior to start of ICL. Prior to the ICL course, however, many of the mentors were unsure of what their role would be. Those that were able to offer specific activities saw "mentorship" as:

- *Advising and making contacts on their behalf*
- *Advising on how to get the most out of the program plus overall business and customer discovery*
- *Coaching and ensuring that the team stayed on track.*
- *Contribute technical and business knowledge to the team.*
- *General business knowledge, primarily, and the experience of having successfully built a company around an innovative product. I expected to focus primarily on marketing, distribution, and customer discovery.*
- *Identifying potential customers, bringing business knowledge to the team. Helping with the concept of the innovation.*
- *Providing expertise on the landscape of graduate and postdoctoral education.*

6.3 Mentor Role on Team

In reviewing survey results, three archetypes of mentors emerged. These archetypes are based on the mentor's relationship to the team before and after ICL, and the role they played during the ICL process.

1. Mentors: Independent mentors that served as advisors to the project team
2. Team members: Mentors who acted as team members, though had the title of mentor
3. Mentor-Team members: Those that are deeply integrated into the team, but serve as advisors.

Below are explanations of these three archetypes:

The Mentor: The mentor was typically someone who had business and legal knowledge related to scaling or sustaining an innovation, may have had experience as an entrepreneur or investor or other business experience. The Mentor provided advice and guidance, helped interpret findings from the customer discovery interviews and interpret the feedback from the teaching team. These mentors also report providing guidance around business development, for example defining their MVP in response to the interviews. These mentors may or may not have continued to support the team after the course. Just over half of the mentors fall into this category. Example comments from this group include:

- *The academic team members valued my business perspective and incorporated it into each iteration. I found that we all looked at the data differently and my business-based view helped them see the difference between the academic approach and the start-up*
- *Primarily, I found my role to be one of keeping the others focused on I-Corps and learning the business model. They felt that they had a good understanding of what to build, how to build it, and their target market, based on their own experiences. Convincing them to follow the BMC and discovery process as if they didn't already know the answers was a fair amount of work! It was rewarding, though; they had a number of insights which helped change the direction in which they were moving, focus on a specific target, and learn how to select which product features (and accompanying support materials) would be most useful for their customers and hence make them more successful in commercialization.*

The Team member: Mentors in this archetype acted as team members. This group brought the least amount of experience prior to the course, particularly lacking prior experience in the Business Model Canvas and Customer Discovery. These team members often conducted a significant portion of the customer discovery interviews (more likely in Cohort 2) and served as cheerleaders rather than advisors. All of these mentors identify as Type 2 entrepreneurs, in that they want to scale and sustain an innovation within the context of their current profession, they are not primarily interested in starting a company. Often, the team member came from within the university and though they may not have begun as a formal team member, many are still deeply involved with the team. Almost a third of the mentors fit this description. Example quotes from this type of mentor include:

- *Without any prior entrepreneurial experience, I felt that I lacked the qualifications to serve as a mentor. However, I participated with enthusiasm, did about a fourth of the interviews, and helped the team stay focused. One thing that kept coming up initially was their resistance with the process and their dislike of Launchpad central. I tried to nudge them towards accepting it, because resistance was futile.*
- *My role as Mentor allowed me to be on the team. I function now more as a Co-PI with the other members of the Team in continuing to develop the idea.*

The Mentor-Team member: Mentor-team members are typically deeply involved with the team; all mentor-team members were involved with the innovation in the six months prior to the ICL course in a mentor relationship and ICL allowed them to continue this relationship. These mentor-team members draw upon their business and legal knowledge and experience to guide the team. Almost 15% of all mentors acted in this manner. Example quotes from this type of mentor include:

- *Our Team conducted 124 interviews during the summer of 2015. I went beyond the normal Mentor role, in that I: (1) defined a segment of interviewees that the Project Leader would have missed; (2) facilitated certain libraries within the library world; (3) actually conducted about 1/3 of the interviews myself with a segment defined by elected officials, big donors and other major decision makers.*
- *Our team was fortunate to have a strong EL in [Name] and strong PI in [Name]. [EL] was already my employee and direct report so we communicated often mainly to assess customer feedback, generate ideas, and analyze market sectors.*

Mentors and team members were asked in which areas mentors were able to influence the process for the teams. Table M6 provides an overview of ways in which the mentors were influential. Within the survey response options available, mentors provided teams with going through the BMC, interpreting teaching team feedback and reviewing presentations. In the canonical I-Corps, mentors are expected to facilitate introductions for customer discovery interviews. In ICL mentors were less involved in supporting their team's networking.

Table M6: Mentor's perceived influence

Q. To what extent do you feel you were influential in each of the following...	**n**	**Mean**	**Not at all (0)**	**Moderately (1)**	**Significantly (2)**
Guided/advised my team in developing/updating the BMC	38	1.6	1	14	23
Helped interpret/contextualize/apply Teaching Team feedback	38	1.6	1	15	22
Reviewed presentations prior to class	37	1.5	4	9	24
Identified and corrected gaps in team members' business knowledge	37	1.4	4	15	18
Guided/advised my team about the ecosystem related to the innovation.	38	1.3	3	21	14
Mentored team members in one-on-one meetings	38	1.2	5	20	13
Coached team how to network/make phone calls	36	0.8	12	18	6
Provided contacts for funders/investors	38	0.7	16	16	6

Table M7 compares the mentor's perspective with that of the team members. Overall, the team members are in agreement about where the mentor was influential, with the exception of the EL, who seemed to see the mentor as slightly less influential in terms of mentoring on-on-one and reviewing materials prior to class. The mentors ranked themselves as slightly more influential overall.

Table M7: Mentor influence by team member type

Q. To what extent do you feel the mentor was influential in each of the following...

Scale: 0= not at all; 1= moderately; 2= significantly	**Mentor (N=38)**	**PI (n=30)**	**EL (n=40)**
Guided/advised my team in developing/updating the BMC	1.6	1.5	1.4
Helped interpret/contextualize/apply Teaching Team feedback	1.6	1.5	1.3
Reviewed presentations prior to class	1.5	1.5	1.1
Identified and corrected gaps in team members' business knowledge	1.4	1.3	1.2
Guided/advised my team about the ecosystem related to the innovation.	1.3	1.5	1.3
Mentored team members in one-on-one meetings	1.2	1.2	0.8
Coached team how to network/make phone calls	0.8	1.0	0.7
Provided contacts for funders/investors	0.7	0.6	0.7

Despite the variation in mentor type, as illustrated through the three archetypes, there is no correlation to the success of the team nor to the perceived value of ICL. Mentors brought more expertise than the PI and EL in the realms of business and legal knowledge and prior experience with the course fundamentals (customer discovery, business model canvas etc.). Thus, the value of the role the mentor plays is inconclusive and may be highly dependent on the team.

6.4 Involvement After the Course

Since the ICL course, many of the mentors who responded to this survey have remained on the teams. At the time of the survey (which was 8 months to 2 years post-course, depending on cohort) 57% of mentors from teams that still have an active innovation remained involved. Of those involved, 35% are involved with funding (n=7) and most of these mentors identify as Type 1 (5 identify as Type 1 versus 2 as Type 2 mentors). Table M8 provides an overview of what mentors report doing since the course. Mentors who are still involved report guiding their team through the ecosystem related to the innovation, supporting business knowledge, and participating in one-on-one meetings. They have also provided contacts for funders and investors.

Table M8: Post-course involvement

Q. To what extent do you feel you were influential in each of the following...

	n	Involved after ICL course
Guided/advised my team about the ecosystem related to the innovation.	38	10
Identified and corrected gaps in team members' business knowledge	37	9
Mentored team members in one-on-one meetings	38	9
Guided/advised my team in developing/updating the BMC	38	8
Provided contacts for funders/investors	38	8
Helped interpret/contextualize/apply Teaching Team feedback	38	5
Coached team how to network/make phone calls	36	3
Reviewed presentations prior to class	37	1

Again, when looking at the support mentors are providing, there is a difference between Type 1 and Type 2 mentors. Type 1 is more likely to provide business development support and be advisors to the team; Type 2 mentors are more likely to provide industry contacts and provide support through grant writing.

Mentors also discussed the barriers faced by the innovation after the ICL project. All mentors report the greatest barrier was trouble securing key financial resources but Type 1 mentors also report much more difficulty with institutional barriers and challenges due to lack of political support from institutions (Table M9).

Table M9: Barriers faced after ICL

Q. Below is a list of potential obstacles. Please indicate how challenging they were, if encountered by your innovation. Obstacles with the highest variation between mentor types are highlighted.

Scale: 0= not at all; 1= minimal; 2= moderate; 3= extensive; 4= insurmountable

	n	Overall	Type 1 (n=7)	Type 2 (n=10)
Securing key human resources (i.e. time, expertise)	20	2.2	2.6	2.0
Determining viable revenue streams	19	2.2	2.1	2.3
Securing key financial resources	20	2.1	2.1	1.9
The work / cost of supporting the customer relationships	20	2.0	2.0	2.1
Determining a viable cost structure	20	1.8	2.1	1.8
Establishing key partnerships	19	1.8	1.9	1.9
Identifying the appropriate channels to market	19	1.7	2.1	1.6
Lack of financial support from our institution	20	1.5	1.9	1.3
The innovation would take too long to scale	19	1.5	1.9	1.1
Focusing on customer segments	19	1.4	1.9	1.1
Other institutional barriers	19	1.3	1.9	0.9
Problems with the innovation itself	20	1.3	1.6	1.2
Value propositions were not compelling to customers	20	1.2	1.1	1.2
Lack of evidence of the educational efficacy of the innovation	20	1.1	1.4	1.0
Team challenges	20	1.0	1.0	1.0
Lack of political support from our institution	20	0.7	1.1	0.3

Note: The number of responses for Type 3 (n=3) was too small to conduct meaningful analysis.

6.5 MENTOR OUTLOOK ON ICL

Impact on Mentors

Overall, mentors felt that the gains they made from ICL were worth the time devoted to it. As a result of participation, mentors report very modest impact on their mentoring, teaching, and research, likely because fewer mentors are in those positions and more are from non-academic and/or entrepreneurial professions. When asked how it related to their day job, however, mentors report a generally positive impact. Yet several also noted that they are retired and don't have day jobs. Many report greatest familiarity with customer discovery and the BMC. Others report that they have an increased awareness and appreciation for what it is to scale an educational innovation. Some of the comments provided include:

- *The training impacted my world view of product launches and overall customer focus/discovery and I have been able to share that information and other wisdom gained from the experience with my project managers. The experience has driven me to find the right projects and approaches necessary to commercialize successful products. I feel adding I-Corp L Business*

Mentor to my bio-sketch has been beneficial as well to help secure future SBIR funding. (Entrepreneur/Investor)

- *Helped me to "refresh" many of the entrepreneurial concepts (I started up 2 tech companies in the past) and learn new approaches to entrepreneurship business model (e.g. VP and BM canvas) (Other, unspecified role)*
- *Lessons from I-Corps-L have definitely increased my motivation in looking at research projects from a broader view, to include thinking of who are the beneficiaries of our work. And of course validating the initial conjectures. (Faculty)*
- *It provided professional development that I will utilize in my coaching and mentorship. (Non-academic professional)*

Mentor opinion of ICL

Overall the mentors are positive about the ICL program for helping innovations scale and sustain. They embrace the ICL curriculum and find it aligns with their own business experience. Most report that they agree ICL is an effective tool, and will use it other enterprises. Table M10 presents the mentors' perspective of the ICL program.

Table M10: Mentor perspective on ICL

Q. Please rate the extent to which you agree with each of the following statements.

	n	Mean	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
I embrace the I-Corps-L process of customer discovery	38	4.6	0	1	0	14	23
I-CORPS- L is a valuable approach for moving an educational innovation forward	37	4.5	0	0	4	11	22
I embrace the I-Corps-L Business Model Canvas	38	4.3	0	1	2	20	15
Overall, ICL aligns with my business experience and/or philosophy.	38	4.2	0	0	6	17	15
The I-CORPS-L approach is an effective tool I will use with other early stage enterprises	38	4.0	1	1	9	12	15

Table M11 shows the mentors' perspective by type. Overall, there wasn't a substantial difference between mentor types, however Type 1 mentors are more likely to use the tools with other early stage enterprises. Type 1 mentors are more likely to embrace the ICL process of customer discovery and the business model canvas. Although positive about the ICL approach, the Type 1 mentors are slightly less enthusiastic about the ICL approach for moving an innovation forward than the Type 2 mentors. Type 3 mentors have the most variation, however the number of Type 3 mentors is too small to draw conclusions.

Table M11: Mentor perspective on ICL by type

Q. Please rate the extent to which you agree with each of the following statements.

Scale: 1= strongly disagree; 2= disagree; 3= neither agree nor disagree; 4= agree; 5= strongly agree

	Mean (N=38)	Type 1 (n=13)	Type 2 (n=20)	Type 3 (n=5)
I embrace the I-Corps-L process of customer discovery	4.6	4.4	4.6	4.8
I-CORPS- L is a valuable approach for moving an educational innovation forward	4.5	4.3	4.6	4.6
I embrace the I-Corps-L Business Model Canvas	4.3	4.4	4.2	4.4
Overall, ICL aligns with my business experience and/or philosophy.	4.2	4.2	4.2	4.6
The I-CORPS-L approach is an effective tool I will use with other early stage enterprises	4.0	4.2	3.9	4.2

Advice from Mentors

Mentors were asked on the survey if they have any advice for future mentors. Advice was to prepare for the time commitment and embrace the process, and meet the other mentors. Specific comments include:

- *Learn the process in advance. Understand the expectations and be prepared to hold your teams accountable for them. One of the weaknesses of the I-Corp program is that teams are not adequately prepared for the rigors of the program, and it unnecessarily makes it harder. Educating mentors in advance would be the least you could do to help the teams.*
- *Be prepared to spend significant time supporting your team during the 10-week program, and in the early stages participate fully in the customer discovery.*
- *Don't sit back and just be a passive Mentor. Commit as a full Team member and take responsibility for the whole.*
- *I had no experience with my team before becoming their mentor. Luckily we bonded quickly and respect was quickly earned. In a way, having limited knowledge of the idea helped me be objective and provide unbiased support.*
- *I think the process works well if you stick with it. The problem we have encountered is that our product, though valuable, is being offered in a market that requires very low cost structure.*
- *The movement from academic to academic entrepreneur is harder than people expect. Our limiting factor has been the cost of developing a Beta which is a precursor to most of the stable development funding. It has slowed us down by a year or two from our ideal pace.*

6.6 Conclusion

The application and selection process of mentors as part of the ICL teams resulted in large variation between mentors. The mentors' experience on ICL teams varied in terms of the expertise the mentor brought to the team, the role the mentor took during the ICL course, and the post-course engagement of the mentor. Some mentors saw themselves as independent of the team, taking an advisory role; others were team members, and finally a third group took a mentor role, but with a long-term, vested interest in the success of the team.

Most of the time in the ICL course was spent on Customer Discovery, which taps into a limited amount of experience that the mentors are able to offer. Taking full advantage of mentor expertise often depended on the mentor's prior relationship with the team and willingness to continue in this role after the course. In terms of expertise, only a modest number of mentors had experience in the educational ecosystem, which may have been a missed opportunity for some teams.

Despite the variance in the selection, engagement, and maximization of mentor expertise, there is an overall positive attitude towards ICL as a process for moving an innovation forward and as a learning experience on behalf of the mentors.

7. RETROSPECTIVE COURSE FEEDBACK

7.1 Overview

Quality Evaluation Designs led the course evaluations for ICL. Drawing upon this work, a set of follow-up questions was included in the initial survey administrations to better understand participant satisfaction after the immediacy of course participation. They were also asked to reflect on the course and what advice they had for future participants. On the 2015 and 2016 surveys, PIs and ELs were asked about their embrace of the ICL processes and tools and their advice to future teams on the first survey taken post-course. This question was not asked for Cohort 3. Mentors were asked similar questions on their Spring 2017 mentor survey.

7.2 PIs and ELs

PIs and ELs seem to be satisfied with the program, having embraced the ICL processes and tools. ELs have particularly embraced the customer discovery process and PIs have changed the way they approach presenting innovations. Overall, PIs and ELs were similar in the way they have responded to ICL with the exception of the faculty, who report they are more likely to have changed the ways they present innovations (Table R1).

Table R1: Embrace of the ICL processes and tools post-course

Q. Please rate the extent to which you agree with each of the following statements. In my research or other professional activities...

0=Strongly disagree, 1=Disagree, 2=Neither agree nor disagree, 3=Agree, 4=Strongly Agree
Items with the greatest difference (≥.5) are highlighted

	PI (n=42)	EL (n=40)
I embrace the I-Corps-L process of customer discovery	3.2	3.3
I embrace the I-Corps-L business model canvas	2.8	2.8
I seek perspectives of potential users, customers, buyers, decision-makers.	3.3	3.4
I question potential users, customers, buyers, decision-makers in order to understand their needs, without pitching my innovation.	3.2	3.1
I remain flexible to altering an innovation based on feedback from customer discovery.	3.4	3.5
I work with a team in which leadership is shared, based on members' skills and abilities.	3.3	3.3
When presenting an innovation, I keep it brief and focus on exactly what the audience wants to know.	3.4	2.9

There was little variation by cohort between the PIs, however there were some differences between the ELs by cohort. Cohort 2 seemed to be more satisfied with the course (Table R2). This might be due to the

shift in approach by the teaching team to be more accommodating of scaling and/or sustaining versus commercialization and a shift in how feedback was delivered.

Table R2: EL embrace of the ICL processes and tools post-course

Q. Please rate the extent to which you agree with each of the following statements. In my research or other professional activities...

0=Strongly disagree, 1=Disagree, 2=Neither agree nor disagree, 3=Agree, 4=Strongly Agree

	Cohort 1	Cohort 2
EL	**(n=22)**	**(n=18)**
I remain flexible to altering an innovation based on feedback from customer discovery.	3.2	3.7
I seek perspectives of potential users, customers, buyers, decision-makers.	3.3	3.6
I embrace the I-Corps-L process of customer discovery	3.1	3.6
I work with a team in which leadership is shared, based on members' skills and abilities.	3.2	3.4
I question potential users, customers, buyers, decision-makers in order to understand their needs, without pitching my innovation.	2.7	3.5
When presenting an innovation, I keep it brief and focus on exactly what the audience wants to know.	2.8	3.1
I embrace the I-Corps-L business model canvas	2.7	2.9

PIs and ELs overall satisfaction was strong, with most agreeing or strongly agreeing that the time demanded by the course was worth the time. PIs appear to have benefited slight more than ELs by expanding their network to include other team members and the trainers and experts from the course. That said, there does not appear to be any substantial collaboration across ICL teams (Table R3), however Cohort 2 PIs and ELs were more likely than Cohort 1 participants (with half a point difference for both PIs and ELs).

Table R3: Overall satisfaction and network expansion

Q. Please indicate your level of agreement with the following:

0=Strongly disagree, 1=Disagree, 2=Neither agree nor disagree, 3=Agree, 4=Strongly Agree

	PI	EL
	(n=33)	**(n=40)**
Overall the gains from I-Corps-l were worth the time devoted to it	3.3	3.3
The people I met from other I-Corps-L teams have proven to be valuable contacts	2.4	2.2
The trainers and experts from I-Corps-L have proven to be valuable professional contact	2.4	2.2
I am actively working with or collaborating with other I-Corps-L participants	1.4	1.2
The experience of spending an intense amount of time as a team increased our team's determination to continue	2.8	2.6

Most comments about the time devoted to the course came from Cohort 1 participants. These participants struggled with a business model that encouraged a commercialization/profit-based model and was better fit for products, thought that wasn't the motivation of all innovations. ELs in particular thought there needed to be a level of business acumen either taught or as a prerequisite.
The participants who found the training to be very or extremely valuable also found the ICL process to be a catalyst for advancing their innovation. Without ICL, the team would not have been as focused, the project would not scale as quickly or to the market as expected and/or been as efficient of a process. These participants also report that their entrepreneurial mindset has influenced subsequent projects and teaching.

PIs and ELs were also asked to reflect on what they would have done differently in ICL knowing what they now know. Most comments to this question are unique to an individual. There were a few minor themes that emerged, but should not be considered representative of all participants. The PIs in cohort 1 would have been more thoughtful about the team member choice to either better facilitate scaling or improve team dynamics. They also would have preferred a little more information upfront. ELs would have been more thoughtful about picking a project- either to be of interest personally or to have greater focus. They also struggled with keeping their PIs on track.

Among cohort 2, PIs mentioned that they would have spent more time preparing by reading the material. The ELs would have revised their approach to interviews- in including who they interview, how they conducted the interviews and when.

When asked what advice the ELs and PIs had for future participants, they overwhelmingly advise incoming teams to clear their calendars in order to maximize the benefit of the ICL program, as they indicate one will need to spend significant time engaging in the process. The customer discovery process is valuable and one can use interviewees to link to other potential customers (snowball) or utilize this contact list after ICL training. Among the PI recommendations were to know you will need to secure future funding; find a committed and cohesive team and; keep an open mind. The ELs also noted that one should trust in the process. Many were pushed outside their comfort zones and advise pushing through the insecurities.

7.3 MENTORS

Overall, mentors report that they embrace the process of customer discovery, the BMC approach, and that ICL is a valuable approach for moving an educational innovation forward. Mentors also report that the time devoted to the course were worth the effort. Table R4 provides an overview of the mentors' level of buy in for the ICL process. The PI and EL means are included for reference.

R4: Mentor embrace of the ICL processes and tools post-course

Q. Please rate the extent to which you agree with each of the following statements.

0=Strongly disagree, 1=Disagree, 2=Neither agree nor disagree, 3=Agree, 4=Strongly Agree

	Mentor (n=38)	PI (n=33)	EL (n=40)
I embrace the I-Corps-L process of customer discovery	4.6	3.2	3.3
I-CORPS- L is a valuable approach for moving an educational innovation Forward	4.5	-	-
I embrace the I-Corps-L Business Model Canvas	4.3	2.8	2.8
Overall, ICL aligns with my business experience and/or philosophy.	4.2	-	-
Overall the gains I made from I-Corps-L were worth the time devoted to it	4.0	3.3	3.3
The I-CORPS-L approach is an effective tool I will use with other early stage enterprises	4.0	-	-

Mentors were asked if they had any feedback that could inform the future ICL offerings. They offered feedback on the instructors, the structure of the program, and some more general items.

- Instructors: Mentors felt that the instructors were "confrontational and dogmatic." They felt the aggressive approach to feedback was not needed.
- Course process: Some mentors noted that there were teams that were not ready for the rigor of the program. This might be that they were not personally committed and invested in the course, or that the innovation was not fully developed. Another suggestion was to allocate more time between the end of the interviews and the final presentation to allow teams to fully reflect on what they had heard

Course content: There were a few mentors who felt the LeanLaunch Pad methodology, and ICL more generally, was not appropriate for social impact startups.[14] One mentor said:

> *Trying to shoe-horn educational innovation into the I-Corp format risks many kinds of potentially useful educational innovations that don't fit well into the limited perspective of the overall I-Corp approach. That overall approach tends strongly to favor incremental innovation over breakthrough innovation, consumer over enterprise innovation (which requires much more than an MVP to prosper) and very often confuses limited niche adoption of an MVP for the textbook early adopter market that startups actually need to find -- i.e., one whose need is experienced acutely ahead of the general market, but will be adopted by the general market over time. There are many other limits to the Blank/I-Corp approach in different contexts.*

Similarly, some mentors thought more attention was needed to the business side of the organization, particularly figuring out viable cost structures.

[14] Lean LaunchPad is an approach developed by Steve Blank to facilitate rapid start-up (and failure) for entrepreneurs.

8. INTERVIEW STUDY:

TEAM MOTIVATIONS, INTENTIONS, SUPPORTS, AND OBSTACLES

8.1 Study Background and Design

In addition to the longitudinal surveys, qualitative data in the form of interviews were collected and analyzed in order to gain a deeper understanding of the development of innovations after ICL training. We interviewed 43% (26/60) of PIs whose innovations were still active 1-2 years after ICL training in order to describe innovation activity and identify obstacles and supports influencing the development process.

Initially, we hoped to characterize the ecosystem(s) within which innovations sustained and scaled. We used the Business Model Canvas in order to operationalize *ecosystem*. Professionals in the field, including members of the advisory board, felt that the approach did not adequately represent the complex interactions that characterize an innovation's ecosystem. Furthermore, even though teams we interviewed were active, some had not ventured into an ecosystem, while others were deeply engaged. Instead, we focused on the motivations, intentions, supports, and obstacles that become the basis upon which a business is built and influence whether and how an innovation develops and ecosystem.

The I-Corps™ program is expressly intended to import into academia the values and perspectives of venture-oriented entrepreneurship.[15] The dominant narrative of entrepreneurship, which is conveyed explicitly and implicitly in the ICL program includes the following:

- Effective entrepreneurs are passionate about their innovations.
- Effective entrepreneurs have IP.
- Effective entrepreneurs start companies.
- Effective entrepreneurs make sales; they aren't dependent on grants, which can be controlling and are unsustainable.
- Effective entrepreneurs quit their jobs to pursue their innovations.

From the very first ICL pilot cohort (Jan/Feb 2014), course participants evidenced significant variation in their motivations for sustaining and scaling their learning innovations. Quality Evaluation Designs (QED) identified three distinct motivational dispositions. These are explained below, with approximate proportions found across ICL cohorts:

- *Entrepreneurial-Leaning (25%)*: wants to be an entrepreneur and succeed in the start-up world.

[15] Blank, S. (2011). Embrace failure to start up success. *Nature News*, *477*(7363), 133-133. Available at: https://www.nature.com/news/2011/110907/full/477133a.html. Last Accessed 16 Aug 2017. Also see: Swamidass, P. M. (2013). University startups as a commercialization alternative: lessons from three contrasting case studies. *The Journal of Technology Transfer*, *38*(6), 788-808. Also see: Gouma, P. I., & Lee, J. (2014). Photocatalytic nanomats clean up produced water from fracking. *Translational Materials Research*, *1*(2), 025002.

- *Current Profession-Leaning (40%)*: Not so interested in starting a company. Wants to sustain and scale an innovation within the context of one's current job/profession.
- *Both Equally (35%)*: Wants to sustain and scale an innovation and succeed in the start-up world AND in one's current profession.

Interviews with and surveys of ICL alumni consistently revealed motivations for sustaining and scaling innovations that differ considerably from those of the dominant narrative bulleted above. In contrast to the dominant narrative, the *majority* of ICL participants:

- Are more passionate about educational transformation and/or social change than they are their innovations.
- Do not desire to start companies.
- Do not have IP
- Intend to support their innovations through grants (although some intend to use grants only until the innovation is self-sustaining).
- Do not intend to quit their jobs in order to develop their innovations.

What does innovation look like when it stems from such motivations? In the current study, the research team explored the following questions:

1. *What does innovation development look like after ICL?*
2. *What are the supports and obstacles PIs face in sustaining and scaling education innovations?*

Method

This study began with interviews with experts from entrepreneur incubators. Expert interviews enabled researchers to focus on issues that were explored further with a round of interviews with ICL PIs and ELs.

The research team sought to identify key factors associated with continued innovation development. A total of 64 teams participated in ICL from July 2015 through August 2016 and, of those, 60 teams reported in Spring 2017 that they were continuing to develop their innovations. The research team first conducted exploratory interviews with a small subset of these respondents, who were selected initially from those who indicated on ICL Longitudinal surveys that they would be willing to talk with study researchers. Based on those interviews, the protocol was refined and more teams were contacted through emails and follow-up phone calls. Altogether, we interviewed members of 26/60 (43%) of these teams, who were either the lead on the innovation or who were intimately familiar with project details. Researchers entered responses directly into a Survey Monkey template during interviews (see Appendix M for Interview Protocol). Subsequently, several items were quanticized[16] and summarized. These data

[16] Cresswell, J.W. (2003), *Research Design: Quantitative, Qualitative, and Mixed Methods Approaches*, Second Edition, Thousand Oaks, CA: Sage Publications

were analyzed in Excel. *Post-hoc analyses* revealed that teams that were interviewed represented those that were most active (see chapter 3).

Based on the data, the research team conducted thematic analyses and, in some cases, created variables, which were analyzed descriptively. Brief descriptive narratives—caselets—were created for seven cases that reflect the range and diversity of motivations and experiences found across the data. Based on all cases, certain patterns emerged across variables. Although there were too few cases to conduct meaningful inferential tests, crosstabs were conducted (presented in section 8.10), which show trends for combinations of variables.

8.2 Illustrative Cases

The ICL program encourages faculty to 1) assess the viability of an innovation for scaling, and 2) scale innovations deemed to be viable. Since nearly every team that has participated in ICL made a *Go* decision, the outcomes of those decisions are important in order to assess ICL curriculum and outcomes.

In spring 2017, we interviewed 26 PIs of teams that were reported on project surveys to be active, asking questions about innovation activities, whether they formed a company or worked within the umbrella of their current institution, supports and obstacles, current and projected funding sources, and intentions to scale their innovations. We analyzed the data quantitatively and qualitatively. Several questions were summarized as variables.

In this section, seven caselets give readers a feel for the complexities, nuance, and multi-faceted nature of innovations discussed by our interviewees. The caselets are intended to be brief yet illustrative, providing context to auxiliary analyses. Project researchers assured confidentiality to those we interviewed. In order to preserve that assurance, names, gender, and details about innovations have been altered. Quotes are real, as are essential facts about innovation features and the ecosystem within which innovations seek to sustain and scale.

A key variable that emerged was *Propensity To Scale.* This variable summarizes two factors that appear to be precursors to scaling: a) PIs' *intended sources of supporting the project after start-up*, and b) whether the PI has *devised* a *plan for scaling*. These variables are discussed below. Intended sources of funding after start-up was considered a proxy related to intention to scale. Levels of the variable are shown in Table E1.

Table E1: Intended Funding After Start Up

Weight	Descriptor
0	Personal Funds Only or Don't Know
1	Grants and/or Institutional Support Only—Sustain Only
2	Grants and/or Institutional Support Only—Intention to Scale
3	Grant, Sales, and/or Institutional Support
4	Sales and and/or Investors

One ICL faculty member summarized the thrust of ICL as *beyond me training*; teaching participants to expand the value of their innovations beyond their institutions and immediate collaborators. The rationale behind the intended means of funding metric is that the higher the rating, the more likely the PI team intends to seek customers outside of the innovator's immediate network, and therefore the greater the need to identify strong value propositions and customer segments.

Existence of a plan for scaling, the specificity of a plan, and whether a plan has been shared reflect the extent to which actual planning and strategizing have taken place. If a specific plan has been developed and shared, it suggests greater commitment to the project than if a plan has not been devised or shared with business associates and/or partners. In our sample, shared plans often reflected working relationships with university administrators, business experts, key partners, and/or investors. The weighting of the *Plans for Scaling* variable is shown in Table E2.

Table E2: Plans for Scaling

Weight	Descriptor
0	No plan
1	Vague idea, no clear steps
2	Steps to scaling outlined, but no specifics
3	Specific plan with details, but not shared with others
4	Specific and shared scale plan

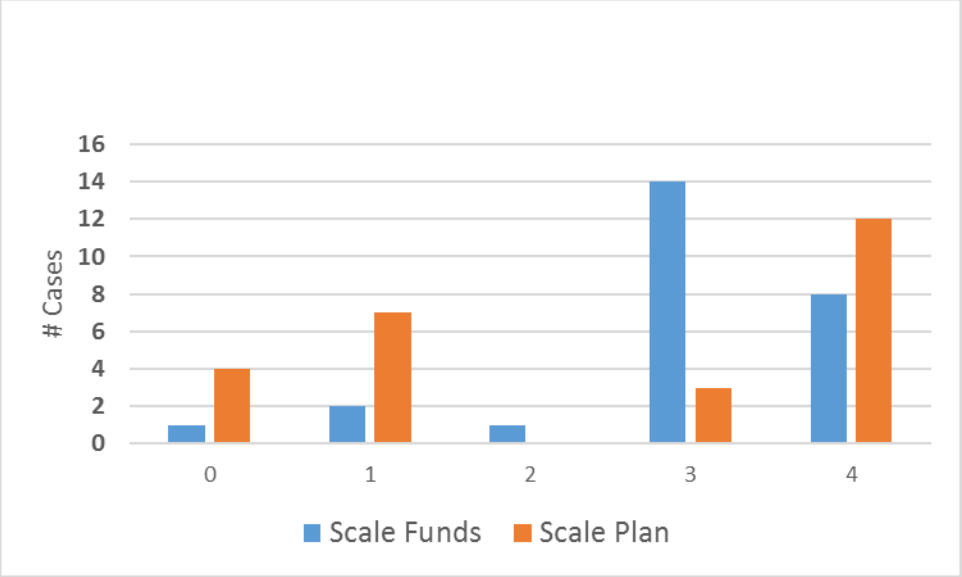
Intention and *planning* have been cited as precursors to successful startups in the research literature. Kreuger (2000) writes:

> *Intentions are the single best predictor of any planned behavior, including entrepreneurship (p.412).* [17]

[17] *Krueger, N. F. jr., M. D. Reilly and A. L. Carsrud, (2000).* Competing models of entrepreneurial intentions, *Journal of Business Venturing, 15, 411-432.* Also see*:* Van Gelderen, M., Thurik, R., & Bosma, N. *(2006).* Success and risk factors in the pre-startup phase*.* Small Business Economics*,* 26*(4), 319-335.* Also see: Lussier, R. N. (1996). A startup business success versus failure prediction model for the retail industry. *The Mid-Atlantic Journal of Business,* 32*(2), 79.* Also see: Van de Ven, R.H., & Schroeder, D.M. (1984). Designing New Business Startups: Entrepreneurial, Organizational, and Ecological Considerations. *Journal of Management,* Vol 10, Issue 1, pp. 87 – 108.

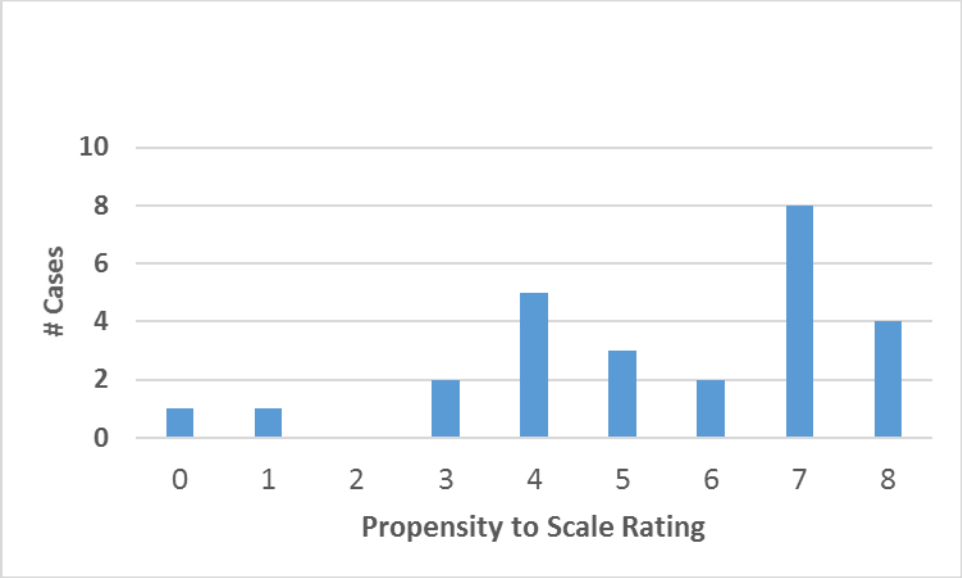
Among the 26 cases in this study, these two variables correlated mildly at r^2=.284 ($p<0.05$), suggesting they measure different facets of an underlying phenomenon. Distributions of the two variables are shown in chart 3.3, below. These data show that although nearly all respondents intend to scale their innovations, many have not created specific plans for doing so, and among those who have, nearly half have not shared those plans with others. Among PIs we interviewed, 23/26 (88%) of PIs expressed an intention to scale their innovation. However, only 14/23 (61%) of those had *specific* plans for achieving their goal, yet 11/14 (79%) who had specific plans had shared them with business associates or partners.

Figure E1: Frequency Distributions of Intended Scale Funds and Scale Plan



Combining the *Intention* and *Planning* variables created the combined variable, *Propensity to Scale (PTS)*. *PTS* range was 0-8, with a mean of 5. The distribution, shown in chart 3.4, is bi-modal, with several cases clustered at 4 and at 7.

Figure E2: Frequency Distribution of Combined Variable: Propensity to Scale



PIs with whom we spoke had varying levels of business acumen, institutional support, and motivations sustain or scale their innovations. The following seven caselets provide color and shading to Figures that summarize innovation development. *Propensity to Scale* is only one facet of innovation development. The descriptions below attempt to reflect the complexities involving a broad range of factors that influence ICL PIs' innovation efforts, which is discussed in *Section III* of this report.

The seven cases below were selected for their representativeness in terms of their scores on the *Propensity to Scale* variable. Cases 1, 2, and 3 scored above the mean; cases 4, 5, and 6 scored near the mean, and case 7 scored far below the mean.

8.3 CASE 1: ADVANCED INSIGHTS (AI)[18] *—Non-Profit **COMPANY**: Propensity to Scale = 8/8, (Projects $3m-$7m/yr. in 5 years)*

Advanced Insights (AI) is one of the 31% (n=8) teams in the data that is motivated to scale its innovation *moderately*. *Moderately* is in relation to its current level of growth, which is already substantial. Dr. Mapleton, the PI, formed a non-profit company, which is housed within the University. This innovation exemplifies one of the many hybrid company/university administrative structures among active ICL innovations. Although the innovation is a non-profit, revenue flows directly to the University and is distributed out to the innovation, which operates as an independent unit. The innovation already brings in several hundred thousand dollars each year. AI seeks to grow in terms of users without increasing the size of its staff, which is why we estimated growth as *moderate*. AI's *Propensity to Scale (PTS)* rating is 8/8, one of four innovations with maximum PTS scores.

[18] All names (innovations and faculty) are pseudonyms. Gender may have been altered. Furthermore, details about the innovations have been changed to preserve confidentiality.

Background and Context

AI trains undergraduate and graduate students in career advancement skills. The project is a spin-off of a former NSF grant, which ended. The PI created a non-profit for the project, but AI is housed as a unit on campus. Revenue, generated by institutional subscriptions, flows to the university and then to the unit, which sustains four, full-time employees, hosts a large, annual conference, and facilitates programs at 200 universities throughout the world.

Dr. Mapleton acknowledges the value of ICL for moving AI ahead:

> *I would say that ICL was instrumental in our process of defining a sustainability strategy. It provided us the right framework and focus that our team needed to execute effectively. It was hard but it was worth it. The strict process gave us a lot of safety and cover in which we were able to really explore and experiment without adverse ramifications. Without that, it's questionable what our path would have been so we're very lucky and grateful to have had the experience of participating in the ICL workshop. We executed on the vision that we originally outlined in the ICL workshop. We doubled our price, we went global, and exceeded our budgetary targets.*

Signing onto AI requires input from several Buyers and Decision-Makers; however, the project has become known and customers seek out the program. The program has no competitors.

AI Obstacles & Support

Across the dataset, we saw wide variation across institutions in term of their climate and tolerance for innovation. Dr. Mapleton speaks positively about the supportive environment at her institution:

> *I would say that we're encouraged to think creatively and innovatively about how we achieve our impact. I've seen support like none we have experienced previously.*

Dr. Mapleton reflected on the opportunities and challenges working within a large university. On the one hand, AI has to be mindful of institutional priorities and practices, and incorporate those into day-to-day interaction and long-range planning. On the other hand, the existence of AI on campus provides new networks for the institution, through which to expand its mission and reach. The University provides much-valued space to house the program and host meetings and conferences. AI has benefitted from the talent of staff, faculty, and students at the institution, to which the PI does not believe they would have had access otherwise.

> *[Key supports have been] access to amazing talent, access to industry leaders, and physical space. We have an actual project space and [we can reserve meeting space,] which is very hard to get. Given that the conference/meetup is such an important part of our product portfolio, ready access to facilities/talent/network is vital for what we do.*

AI's Propensity to Scale

AI's *PTS* rating is 8/8. The project started from a grant and relied on grants through its sustainability phase. Now AI relies exclusively on revenue and does not seek or rely on grant funds. Dr. Mapleton explained:

> *One of the agreements with our University was to shy away from grants. While we probably could have easily gotten grants, we deliberately did not pursue any grant funding. It can tie your hands in what you can do. [We] we believe strongly in getting revenue and we aren't about seeking handouts (grants) that are unsustainable.*

The project has been deliberate in its planning, and has been guided by a specific scale plan that has been created and shared with partners and advisors. Business experts sit on AI's advisory board and have been closely involved in project development.

AI regularly attracts interested universities and requests from foundations and companies to sponsor the project. Dr. Mapleton said she envisions the project will "double or triple" in five years. However, AI leaders seek to add individuals and institutions to its network without increasing its staffing:

> *We would like to scale impact but not necessarily scale our footprint or our operations in terms of staff. We have to think carefully about how we scale our impact, and additional funding could enable us. We have reached nearly 200 campuses, and trained over 1,000 students. We could potentially expand the number of campuses we reach, but at this point we want to increase our impact at the campuses we have.*

Although AI is highly entrepreneurial, its primary mission is to create social impact, not to generate revenue. Dr. Mapleton said:

> *We have effectively scaled our product offerings in order to break even on our budget, which was our original goal…We continue to have conversations where we've told people we aren't seeking funding but they're still offering funding to us.*

8.4 CASE 2: GOBUILD (GB)—*LLC + Unit in University: Propensity to Scale = 7/8 (Projects $8.5 million in 3 years)*

GoBuild (GB) is architectural design software that has built-in rubrics for assessing the effectiveness of a building's design. This project is a spin-off of a prior grant to design a hands-on architecture course: the GoBuild software was originally designed by the computer science department for the grant-funded architecture course. The PI, Dr. Lindsey, recognized a broader application for high school and college students, as well as professionals, and formed an LLC. However, currently the project operates as a unit within the university. All IP and licensing is owned by the university, but will switch over to the LLC after grant funding ends. Aside from the grants, the university provides financial support. Dr. Lindsey has also used his personal funds. The hybrid nature of the administrative structure and operations is common

within the dataset. GB is among 55% of innovations that intend to *grow moderately* or *a lot*, and among 31% of innovations (8/26) anticipating annual revenue in five years' time between $5m-$50m. GB's *PTS* rating is 7/8, above the mean of our sample.

Background and Context

Dr. Lindsey has prior experience generating innovations. He saw ICL as a way to explore the market opportunity presented by the GoBuild software. ICL was a valuable boost to the project:

> *I felt that the ICL program was very good and helped us clarify our thinking – it helped us build the prototype and build potential for how we make our research practical so we can actually use it in society. Going through ICL gave us some knowledge of what customers are looking for. We built a platform based on what we learned from that - we got 145 good interviews and used that information.*

Customer discovery also helped Dr. Lindsey recognize a market opportunity, due to the fragmented nature of potential competitors:

> *The market is very fragmented - mostly mom & pop or local organizations that are working to create design software in some form. We offer a standardized rubric. What we're doing is creating a web-based platform that compliments a portfolio already created that already has 50,000 users.*

Buyers and Decision-Makers are high school district teachers and administrators. As is typical with the pK-12 system, purchase typically starts with a motivated teacher or curriculum specialist, then involves one or more administrators. The market is sometimes difficult to find, but those who teach the subject matter have already sought out GB, and others may follow. National interest in incorporating more hands-on STEM in pK-12 curricula has generated much interest in GoBuild. Channels are a GB website on the University server and distribution by partners, especially publishers.

Dr. Lindsey has created an LLC for GoBuild, but won't transfer operations to the company until after two existing grants run out. Currently Dr. Lindsey manages all the administrative tasks for the project because he does not want to use grant-funds for administrative support. All licensing agreements were negotiated through the University, which is also managing several sub-contractors, including web design and support. The project is still in the prototype stage, but when it launches a pilot, the development team is targeting 1700 users. Meantime, the project has applied for two patents and the name has been trademarked.

GB's Obstacles & Supports

Dr. Lindsey's biggest challenge is piloting the modules with high school students and college freshmen, since all research has to go through the IRB process, which limits his ability to contact students under 18, and also raises conflict-of-interest issues, due to GB's status as an LLC and a university unit. He said:

> *I think the major obstacle for me is compliance - university IRB or other compliance that I need to file, plus all the taxes. The University owns part of GoBuild...it's a big effort. Not that it's not necessary. It's just hard to do the research and then try to comply with all these issues that continually come about throughout the year.*

In spite of accounting challenges related to the dual status of the project (being an LLC and university unit), Dr. Lindsey did not say that he could benefit from further business support. The University, which currently owns all the IP, negotiates the licensing and provides other legal and financial support. If two current NSF grant proposals are funded, the project will scale nationally, and at that point he will hire administrative support off of those grants. He said:

> *… I don't have much support because I don't want to use my administrative support. A lot of it is stuff I have to fill out and process. I think what we're doing now with these new NSF proposals (which would involve larger scale-up around the country) - we did put in for administrative support. We would need to file with different states then--a lot of administrative compliance work.*

GoBuild's Propensity To Scale

GB intends to support the innovation through a combination of grants, sales, and institutional support. The project is guided by a specific and shared scale plan, developed in conjunction with university administrators. Although GB had not generated sales by spring 2017, software and training were expected to roll out in summer or fall 2017. GB has a very specific and detailed scale plan, divided into customer segments, and organized into two sections: *software product* and *professional training*. This plan has been shared (and in some cases developed) with University lawyers, partners involved in publishing and marketing, and venture capitalists. Dr. Lindsey's projections of bringing in $8.5m in revenue within three years are based on market research and input from partners.

8.5 CASE 3: ENGINEERING EXPLOITS (EE)*—C-Corp: Propensity to Scale = 7/8 (Projects less than $100,000/yr in 5 years)*

This is one of the 27% (n=7) teams that formed a company. Dr. Gee's team formed a C-Corp; however, like several teams in our sample, the project also operates as a unit within the university. Dr. Gee has a specific definition of the scale that he would like to reach and a strategy for achieving his target. As with other PIs in our sample, University bureaucracy frustrates him, and he admits he lacks the business experience to know both what he should do next and how to navigate his innovation to the next level. Nevertheless, Engineering Exploits (EE) rated 7/8 on the *PTS*, above the mean of our sample.

Background and Context

Engineering Exploits (EE) creates manipulatives that enable middle- and high-school students to do hands on learning of engineering. The manipulatives are accompanied by videos that illustrate key concepts. EE has received several grants, including a large NSF grant, the ICL grant, and several state grants. The team has won competitions that have included cash awards. Approximately $200,000 has been generated from licensing and distribution agreements.

EE currently operates within the pK-12 ecosystem. Middle- and high-school teachers are the primary decision-makers, often requiring agreement from principals and district administrators for purchasing. Dr. Gee hopes eventually to expand EE into colleges and universities. Like other innovators in the pK-12 ecosystem, identifying adopters is challenging. Progressive teachers interested in doing hands-on instruction are not an easy-to-identify population. Dr. Gee believes in his product and believes that it will be successful. He foresees no threats from competitors:

> *Our biggest competitors have models that are just not going to work. There's several packages that charge $50/student per semester and I think they're going to go out of business. To me it seems like a pretty young ecosystem where there are possibilities for innovation.*

EE Obstacles & Supports

Although EE is a C-Corp, the company does not act autonomously. Some funds go to the University and some go to the company, which creates challenges for Dr. Gee:

> *It's kind of a mess. I'm not an accountant so it's been very confusing for me. Some of the grant money goes to me because I'm at the University and that remains housed at the University. Then other grant money comes to us as a company and that's housed in our company account. Within the University, each grant has its own account and they expire at different times and so it's been a challenge to keep straight where all the resources are. We've also received money from our distributors--not from sales but one chunk of money was just for licensing fee, an exclusivity fee, we've gotten advances. All that money goes straight to the company.*

The University has provided valuable in-kind support, including video equipment and space for designing manipulatives and making videos. Yet, Dr. Gee struggles to manage the innovation while also teaching and conducting research as a full-time faculty member. His co-PI has taken the year off from his faculty job and is being supported by his family to work on the innovation full time. The project has funded consultants to help produce the materials and support other facets of the business. But EE distracts Dr. Gee and his co-PI from their primary mission of improving engineering education. Dr. Gee said:

> *Some obstacles that we face are lack of time and money. I'm still working a full-time job and doing a bunch of other stuff and my partner on this is focusing mostly on this project*

this year. But we're just two people; we need more time and more money. I just want to say that it's so hard. We're busy, and, basically, we're engineers.

EE's Propensity To Scale

EE rated 7/8 on the PTS. Dr. Gee intends to support EE after start-up with grants, sales, and institutional support. Dr. Gee envisions growing the company five-fold in five years, bringing in at least $300,000/yr by 2022. The strategy for doing this has been shared with his co-PI and it is built into their business plan. Yet Dr. Gee admitted throughout the interview that he needs business expertise, and in particular, an accountant.

Dr. Gee said that the team has conducted extensive customer discovery, mostly due to ICL. As a result, the team has fleshed out its Business Model Canvas (BMC). Dr. Gee points to the licensing and distribution revenue as proof of the model, but admits:

I still kind of feel like I have no idea if it's going to work. The big unknown is: Are teachers who are happy to use our resources for free—can we convert them into paying customers? That's a big "if."

8.6 Case 4: Novel Technology Applications (NTA) *Non-Profit Organization + LLC: Propensity to Scale = 4/8 (Projects $100m/yr in 5 years).*

Novel Technology Applications (NTA) combines learning sciences with STEM disciplines to create kits for hands-on learning in classrooms or informal education settings. The prototype product is an electronic thermometer that students of all ages can build and then use for environmental explorations. Dr. Parker, the PI, has formed a non-profit company in order to receive grants for research and development, and an LLC to manage technology transfer agreements. Dr. Parker is unusual in our sample because she is not affiliated with a university or other organization. She is developing NTA using grants and her own funds. Her financial target is among the top 8% of our sample (2/26). NTA's PTS rating is 4/8, near the mean for this sample.

Background and Context

Like several other innovators we interviewed, Dr. Parker struggles from lack of business expertise. Dr. Parker operates a small firm devoted to pK-12 STEM teaching and professional development. She has created kits that give students hands-on experiences studying various STEM disciplines. The NTA kit received great interest from school teachers and university researchers, and Dr. Parker has been a partner on several, large, engineering education grants from NSF. She has created a non-profit company to be eligible for grants and an LLC for licensing and technology transfer. She has paid a lawyer and used an accountant on an as-needed basis. Dr. Parker's non-profit status has enabled her to be included with university partners on three NSF grants. She applied for and was awarded a large NSF grant on her own, but her small business did not meet the NSF finance office criteria for funding the award.

At this point, Dr. Parker supports the innovation mostly from personal funds. She has done extensive customer discovery, including ICL, and believes that there is a broad customer segment/value proposition alignment, and great market potential for her innovation. But lacking business expertise and affiliation with a university have hindered her progress.

> *I'm feeling that I have a great foundation from what I learned from ICL, but honestly I'm feeling like it wasn't enough for people who actually want to move forward and don't have the infrastructure of a university innovation spin-out and support network. And I don't have an MBA...If ICL is going forward in the future, maybe you could have a part two for those who do okay and need this assistance to keep going forward.*

NTA's Obstacles & Supports

Dr. Parker's challenges stem from being a small, independent non-profit company. Her expertise is in education, not in business. She said:

> *I need more information and assistance to Figure out where to go with all these forks in the road. Because I can't keep adding people and dumping more of my own money when there's no real path forward. I'm feeling that I have the basis and a great foundation from what I learned from ICL, but honestly I'm feeling like it wasn't enough for people who actually want to move forward, and don't have the infrastructure of a university innovation spin-out and support network. And I don't have an MBA. I'm a 501c3 educational institution. I know I'm a salmon swimming upstream and I understand if I'm alone. But to really, truly help move forward educational innovations, they aren't all going to come from universities, so I would ask for special thought being given to non-university applicants in the future.*

Dr. Parker cites her professional contacts and university partnerships as her biggest supports. She is encouraged to continue developing NTA by feedback she has received from partners and potential customers:

> *I know there's a need. I know it's viable - it's just figuring out the black box in the middle.*

NTA's Propensity To Scale

Dr. Parker rated 4/8 on our PTS. After start-up, she plans to support the innovation through sales and investors. However, she has no specific plan for scaling, nor did she identify partners or mentors with whom she has shared a plan for scaling. Nevertheless,
Dr. Parker remains committed to pursuing NTA:

> *I would love to have a maker kit on the shelf of Walmart - following what Lego did a few years ago. For units, I would love to see a couple million units sold every year, but that would be a range of products from $5-$50.*

NTA operates within the pK-12 ecosystem. As with other such innovations, customers for NTA are found in pockets within schools and districts that are not easy to target directly. Those interested in hands-on STEM activities and products may find NTA online or learn about it through Dr. Parker's professional development workshops. As with most public school purchases, customers include teachers or curriculum developers who show initial excitement, and administrators who decide whether to release funds. Currently, Dr. Parker sees no threat from competition because there aren't other products that combine maker-type kits with STEM exploration in real-world environments.

Dr. Parker sells NTA from her company website, and also promotes the innovation during professional development workshops she leads. She envisions "doubling or tripling" the size of her company, but actually, her monetary goals are far larger. However, her vision lacks specificity and she has no concrete plan for attaining her financial goal. Instead, she works hard and takes advantage of opportunities when they arise. She admits, however, that she's struggling:

> *There's tremendous interest, but trying to Figure out a pathway to bring this to market instead of cobbling on everyone else's projects [is a challenge]. I know there's a need. I know it's viable - it's just figuring out the black box in the middle.*

In spite of the challenges, Dr. Parker is committed to making NTA successful. She said, "I'm not giving up. I need to take a step back and find another way forward."

8.7 CASE 5: YOUNG EXPLORERS PROGRAM (YEP) *Not a Company: Propensity to Scale = 4/8 (Projects $2-4million/yr in 5 years)*

The Young Explorers Program (YEP) provides materials and professional development to teachers in formal and informal learning environments to promote early childhood STEM learning. Materials are sold as self-contained lessons with hands-on manipulatives and instructions for promoting hands-on learning of STEM concepts. YEP is not a company. It is housed within an education agency supported by a network of schools, grants, libraries, and museums. Although initially intended to serve the region, YEP has been adopted by organizations outside the area, even in other states. YEP has generated a positive response and seems to be a viable innovation. However, the PI, Dr. Lott, admits that he is out of his depth on the business side. He foresees a potentially huge market for YEP locally and nationally, but lacks the knowledge for scaling the project. In this regard, YEP is an example of several projects in the sample run by PIs who have evidence of the viability of their innovation and would like to scale it, but don't know how. YEP rated 4/8 on the *PTS*, near the mean of our sample.

Background and Context

YEP is housed in a state-funded agency, where the PI operates and oversees a small staff and several regional programs. The agency has an annual budget and is supported by partnership fees from several school districts, and has garnered millions of dollars from grants (mostly federal) for many of its programs. In addition to working on sustaining and scaling YEP material, Dr. Lott conducts professional

development training for formal and informal educators throughout the region. YEP is the only project his agency produces for sale, and since YEP products have been created through grants so far, most units are given away to partnering organizations. Nevertheless, there seems to be a lot of interest. The website generates many inquiries for both units and training and approximately 40 sales have been made so far, totaling $3,000. These sales encourage Dr. Lott. He believes that the interest bespeaks a large market regionally and nationally.

The ecosystem within which YEP operates is largely bounded by the regional collaborations that sustain the agency. But there is a museum in another state that has adopted YEP materials, and interest has been expressed by other school districts and libraries. Because his agency lies at the center of multiple and extensive partnerships, Dr. Lott is potentially tapped into a more accessible market than many of his fellow alumni in ICL. Regionally, YEP is sold primarily through word of mouth and agency activities, but that is at the regional level only. The website generates interest and activity from outside the region. Yet scaling YEP is limited because Dr. Lott sees professional development as integral to the project. Given the context within which YEP is housed, his options are constrained. Furthermore, seeing increased interest in STEM nationally, Dr. Lott identifies the threat from competitors as high. With increased options in the market in terms of materials and professional development, scaling the innovation beyond his regional network becomes more challenging.

Although YEP operates under the umbrella agencies, sales go directly to the project. At the same time, Dr. Lott's salary, expenses, and technical and communication support are paid for by grants and agency resources. This both relieves and adds pressure to sustain and scale YEP. The amount of time Dr. Lott can spend on YEP depends upon the amount of grant funds and revenue from sales that are generated, since Dr. Lott has to justify the time he spends on various projects.

> *One of the reasons this is still going on is that YEP is a natural part of what we normally do; otherwise, I wouldn't be able to work on it as part of my daily job. If we were selling something that didn't involve PD [professional development], which is what my job is, then I don't think this could have worked. I think someone would have gotten very impatient with me spending time to build these kits. But because it provides support in PD, it can kind of chug along.*

YEP Obstacles & Supports

The umbrella agency is supportive of YEP and Dr. Lott's intention to scale and sustain the innovation. It provides space and accounting support. YEP benefits from synergy with other agency projects, which share mailing lists and invite YEP staff to their events, trainings, and conferences. There have been some obstacles, but they have been worked out as they have arisen:

> *We wanted to have a commercial website and it took a long time to run it through levels to see if we were allowed to sell and how the money would run back to our program - which bank would do this, and if we could use credit cards. It was several meetings before we had that Figured out.*

The “several meetings” Dr. Lott refers to may have seemed frustrating at the time; however, they contrast favorably with comments from PIs in universities who have spent several months wrangling such issues with administrators, with less positive results. Dr. Lott operates YEP in a generally positive environment for innovation. He appreciates the benefits provided, which include financial/accounting support and physical space:

> *Our organization technically pays rent for our space to the mother organization and that comes out of our program budget. Other supports are that we also have another unit (center for creativity) that has events and they feature our materials in their agenda. Or if they have a conference, they'll invite us to have a Table . And we help promote them if we have an event. Because we work with all the districts, we have mailing lists and ways to make other districts aware of our initiatives and our materials.*

YEP’s Propensity To Scale

YEP rated 4/8 on the *PTS*. Dr. Lott intends to fund the project after start-up with grants, sales, and investors. He envisions scaling his innovation at least 4x over the next five years. But he lacks a specific plan and he doesn’t see this happening quickly.

> *I would say [YEP won’t scale] as fast as you think we should, but it's coming slowly but surely. I'm petrified - I haven't done much marketing electronically with Mail Chimp. I have a list of 200 people who have come to an event - if I emailed them I might get a few orders and I may not be able to quickly enough fill them all. We have pretty much not advertised other than teacher networks and word of mouth. It's been growing slowly with that.*

YEP is supported by being a regional unit designed to help STEM educators, but at the same time, the structure and operation of the unit hamper the ability of Dr. Lott to practice agile engineering of the business model:

> *We're pretty much letting the innovation set the pace because of the organizational structure we have - I can't afford to work on it unless there's money coming in from YEP to support me. The more we sell, the more I can work on them. I don't have the amount of support for it to just happen. Having said that, we are constantly trying to Figure out how to make the process more efficient and how to get better at designing them, how to get grants to design more so we have more for sale.*

Compounding Dr. Lott’s challenge in sustaining and scaling YEP is his lack of business experience. Everything he knows he learned from ICL, and now that his innovation is past customer discovery, he lacks direction:

I guess we'll see how it goes. I could see us, if all goes well, we could have a website and hundreds more customers. I think potentially all elementary schools in the country would have some use for YEP materials, and maybe libraries and some museums. There's another company out there that makes these products on a larger scale; they were interested in YEP. Potentially we would talk to them about some kind of arrangement where we license things to them. If we continue to scale up, we will have to find a partner who's doing all the sourcing and packing of the materials and we would just need to do the content because we can't do that when we sell hundreds of them here. That's the point where either we can go or not go. We have no business background other than what we got through I-Corps so we would need help and partners for that.

One could argue that, were Dr. Lott primarily interested in commercialization, he could leave his agency and focus on sustaining and scaling YEP, including developing a supply chain and marketing the product. Two important factors limit the likelihood of this happening. First, Dr. Lott sees teacher professional development aspect of his job as integral and his primary motivation is not to generate revenue, but to support educators through his agency's programs.

Second, although YEP seems to be a viable innovation, it may languish for lack of time and experience on the part of the PI. Dr. Lott recognizes the market opportunity—his team conducted extensive customer discovery during and after ICL. Yet he lacks a vision and a plan for exploiting the opportunity. His comment endorsing how much he learned through ICL is effusive, but also double-edged:

I would have to reiterate that the ICL experience itself, has just changed everything. This idea that you have to sell your stuff, that wasn't something we did previously. And the idea that you have to listen to your customer and hear what people want, we should have always done that with PD. It took the ICL experience to be forced to experience that firsthand and see how beneficial it was. It was a huge shift in terms of mind-shift for us and it opened up our thinking here, not just for YEP but everything we do. To learn what people say they need not just what research says they need.

Having internalized the lessons of ICL, Dr. Lott is motivated to scale his innovation. With no follow-on training, it is questionable whether he will be able to move this promising innovation farther than he already has. His situation is characteristic of the 39% (n=9/23) of respondents who desire to grow their innovations *moderately* or *a lot* who lack a specific plan for scaling, presumably due to lack the expertise—or access to expertise—to know how to move their project ahead.

8.8 Case 6: Do The Math (DTM) *Not A Company; Propensity to Scale = 4/8 (Projects less than $100,000/yr in 5 years)*

Do The Math (DTM) is a case of a PI, Dr. Finch, who is interested in growing the innovation minimally, and is not interested in starting a company nor devoting herself full-time to it, because she likes her role as a faculty member. Yet, University bureaucracy frustrates her. Dr. Finch has a vague idea about the

scale that she would like to reach, but does not have a concrete plan for reaching it. Her situation reflects approximately 27% of those in the study who are motivated to scale their innovations *minimally*. DTM rated 4/8 on the *PTS*, just below the mean of our sample.

Context and Background

DTM is a STEM initiative focused on improving how high school math is taught. The project includes professional development and curriculum. Professional development seminars are given online and in-person at workshops and conferences, where math teachers are exposed to and learn how to teach the DTM curriculum. Dr. Finch applied to ICL in order to expand the program, but wasn't necessarily looking to create a viable business venture. Her primary interest continues to be to sustain and slightly expand the program in order to impact math education, especially in high-poverty communities.
Buyers are primarily school districts, which fund teachers to participate. Teachers and district staff are decision-makers. DTM struggles to identify teachers with the background and motivation to participate. Interested and qualified teachers are sprinkled throughout school districts and difficult to target:

> *This ecosystem comes with a lot of nuances--it's multifaceted. … But I am very hopeful, and the fact that we're integrating both the content & pedagogy and it's job-embedded, and the practices are immediate to the classroom, that's hopeful. In other words, all the courses are geared toward immediacy in their practice.*

Customer discovery (from ICL) revealed that more teachers would be attracted if the program offered scholarships, which it has done. Districts' payments for the training generate revenue for the project. These funds used to go directly to a DTM bank account. However, since incorporating certification into the program, funds now go to the university within which DTM operates.

DTM Obstacles & Supports

Since the university approved Dr. Finch's proposal that teachers get certified for the training, workshops are tuition-based. This has created unforeseen challenges. For example, the registrar is now involved, and that office checks the eligibility of each applicant for graduate study based on his or her GRE scores. This has created barriers for some prospective participants.

Also, payment for the training now has to coincide with the University calendar. Payments that come too early each term cannot be accepted, and payments that come too late incur extra charges. Several school districts have been frustrated because the cycle of federal grants that would pay for teacher training do not coordinate with University payment windows. The PI says,

> *There is too much administrative red tape that one has to go through to have the program situated within the university. I have been frustrated many times. There are some things you don't learn until you hit a wall and some things you can't change. When we moved to "on book" there's a change in the subject code and increased funding associated with the code. Additional funds were incurred because the tuition wasn't paid*

> *on time - we are a PD/certificate program so we have to pay fees to academic departments on campus. It's all financial - the little things that the university does to eat away the funding, which I wasn't aware of before.*

Yet Dr. Finch did not mention a need for business support for her innovation. The University does provide Dr. Finch a project director, doctoral student, much-needed team workspace, storage for materials, and website support.

DTM's Propensity To Scale

DTM rated 4/8 on the *PTS*. Dr. Finch intends to support the innovation after start-up with grants, sales, and continued institutional support. Dr. Finch does not have a specific definition of scale and her plan for expanding is vague, relying primarily on a page on the University's website and the video link on the website of the national teachers association.

Dr. Finch would like to grow the program, but needs increased funding to do so:

> *We still need funding sources for it to continue and to offer scholarships to teachers and offset some of the costs…We are seeking funding (I wrote a grant to fund teachers and didn't get it). For us to be successful in meeting many users, we have to find funds to offset costs.*

Nevertheless, Dr. Finch is confident that DTM will grow, saying: "We have our MVP and I'm comfortable that it is viable." The project is preparing a video that will be marketed nationally through a professional teachers' association website. The PI projects serving over 100 teachers/yr, and would like to "double or triple" revenues over the next five years, with revenue/yr after five years reaching around $100,000.

8.9 CASE 7: EARLY STEM LEARNING (ESL) *Not a Company; Propensity to Scale = 1/8 (Seeks to expand modestly with no intention to generate revenue)*

This is a case of a PI, Dr. Rice, who has a very commerializable innovation, but has no interest in scaling it. Rather, he hopes to sustain his innovation indefinitely through grants. He is completely mission-driven, passionate about motivating young children to pursue STEM. Dr. Rice represents the starkest case in our sample of someone who seeks only to sustain an innovation. Early STEM Learning (ESL) rated 1/8 on the *PTS*, far below the mean of our sample.

Background and Context

The Early STEM Learning (ESL) project produces software that engages young children (ages 5-7 years) in STEM. Dr. Rice, the PI, earned degrees in engineering and education and has over 20 years' experience promoting STEM, mostly in pK-12 environments. As a faculty member in a well-known, R1 institution, he has garnered several large grants, mostly from NSF, and ESL has been funded by three consecutive NSF grants.

Dr. Rice applied to ICL primarily as a means of sustaining his innovation through the $50,000 grant award. Operating within a unit on campus, he has no interest in starting a company or scaling the project, but he is passionate about STEM education and in keeping ESL going indefinitely. After ICL, a company expressed interest in distributing the software, but Dr. Rice was not interested, because he is committed to making his innovation widely available at no cost to users. “I am an academic,” he says. To Dr. Rice’s way of thinking, *revenue* implies profit, which implies greed. Anticipated annual revenue/yr in five years is $0, with granting organizations being the sole funders.

Dr. Rice’s large grants enhance the reputation of the University, pay his salary, enable him to support graduate students, and keep him moving up the ranks of promotion and tenure. Of course, the grants provide a sizeable indirect benefit to the University; as a result, Dr. Rice is afforded all the support he needs to promote ESL. In addition to the direct benefits provided by the grant, the University has resourced Dr. Rice with web hosting, space, and professional staff services (e.g., communication, software development).

Dr. Rice writes approximately one to two large grants each year, and gets funding every two to three years. With each grant, he creates new variations to ESL that become, in future years, the basis for further grants.

ESL Obstacles & Supports

Dr. Rice finds that the institution fully supports his grant-making activities and therefore reports no obstacles:

> *I think the university loves the fact that we continue to go out and get grants. With that lens of "we're just going to keep getting grants" - I think the university is very happy with that.*

ESL space and salaries are covered by grants they have received, and Dr. Rice has access to capable graduate students. The university values the dollars and attention the program generates, which results in extensive support.

ESL’s Propensity To Scale

ESL was rated 1/8 on the *PTS*. ESL is supported solely through grants and institutional offsets. Dr. Rice gets teaching releases because of his grants and his graduate students are paid through the grants. His goal is to sustain the project entirely through grants and he has no intention to scale. He expresses no need for business support; he keeps writing the grants and ESL continues to survive in the pk-12 ecosystem.

Although Dr. Rice is not interested in scaling his innovation, sustaining it depends on negotiating the education ecosystem as any innovation would that seeks to commercialize. He has no buyers (ESL is free and downloads from the website), but he does need adopters, who are teachers and sometimes curriculum coordinators. He promotes ESL when he consults with school districts and attends

conferences, but most adopters find the website through web searches and word of mouth. ESL has no external partners. As the focus on STEM education increases nationally, competitors are coming into the market. But ESL content is excellent, and, being free, it still attracts adopters.

Taken together, these caselets defy generalization. Some companies act as units within organizations, some units act like companies. PIs evidence a range of motivations, from no interest in continuing the project beyond grant funding, to sustaining the project indefinitely, to scaling the project minimally, some, or a lot. The magnitude of scale envisioned by the innovators ranged from $0 to millions of dollars. Factors that underlie these variations are discussed in the following section.

8.10 Factors and Themes That Influence Innovation Development

In *Section II* of this chapter, we sketched out what innovation development looks like for several PIs. In this section, we analyze some of the prominent factors discussed by PIs and themes that emerged over the course of the 26 PI interviews. As stated earlier, these PIs and innovations represent the most active teams in our sample.

Prominent Factors

The interview protocol prompted PIs to reflect on key factors that influence innovation development. Key factors are summarized in Table E3.

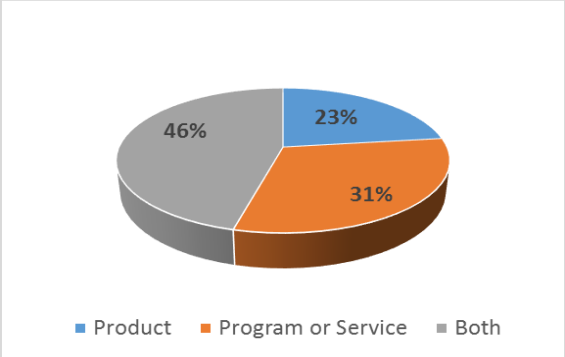
Table E3: Key Factors Influencing Innovation Development

Variable Name	***Categories/Levels***
Minimal Viable Product (MVP)	Product, Program or Service, or Both
Administrative Structure	Company or not a company; if company, what type.
Revenue Flow	Revenue flows to the Company/Unit, or to the Institution
Start-up Funding	Sales, Grants, Investors, Personal Funds, Institution, or a combination. If combination, does it include Grants? Institutional support? Both?
Anticipated Scale funding	Same categories as *Start-up Funding*, plus Not Applicable
Respondent Participation	Paid/Not Paid. Full-time/Part-time.
Intention to Grow	None, Minimal, Moderately, A Lot
Plans to Scale	None, Vague, Specific, Specific and Shared with Others
Anticipated Revenue/yr after 5 years	$100,000 or less; $100,000-$1 million; 1 million-$5million, $5million-$10million; $10m-$25m; $25m-$50m
Business Support	Desires Business Support; Has Business Support; Has Business Support and Desires More; Unknown (=10/26)

Factor Descriptions

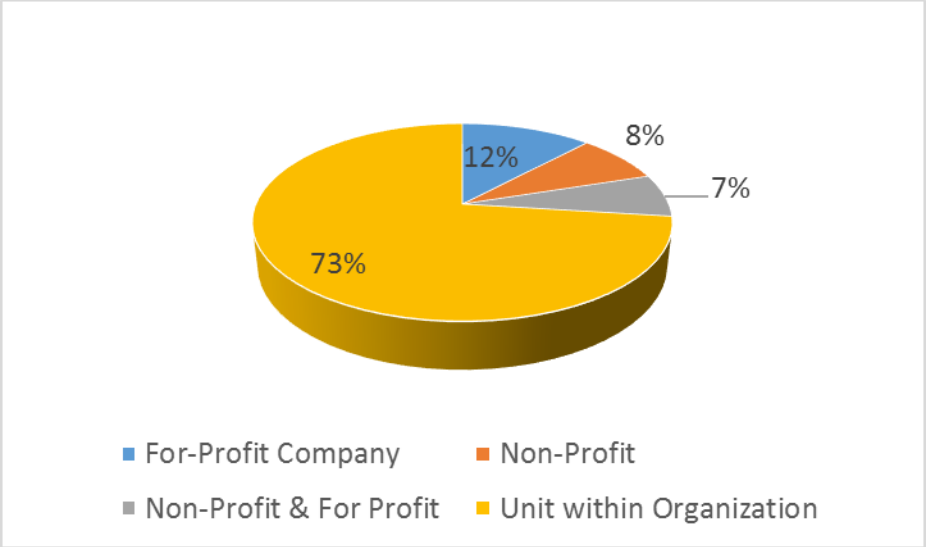
The distributions below are presented in percentages to facilitate comparison. Total n=26, with few missing cases, except *Business Support*, as indicated. Each case accounts for approximately 4% of the total sample. Variation from 100% is due to rounding error.

Figure E3: Minimum Viable Product



- 57% of innovation MVPs include a program or service.

Figure E4: Administrative Structure



- 73% of respondents operate their innovations as units within their institutions.

Figure E5: Revenue Flow

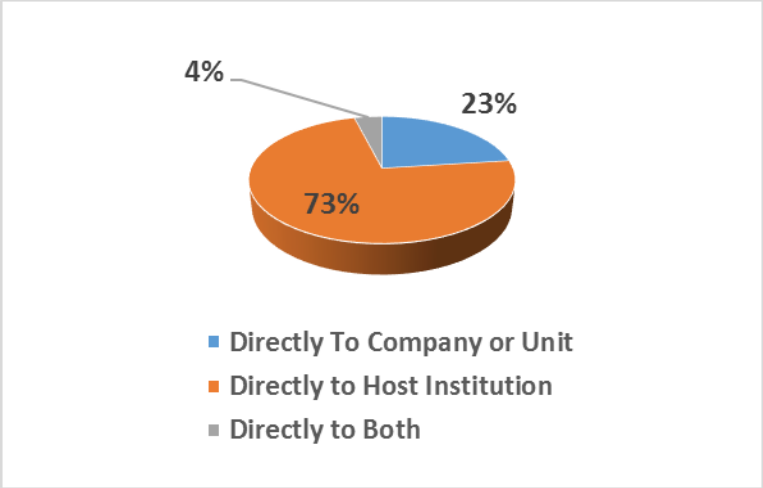
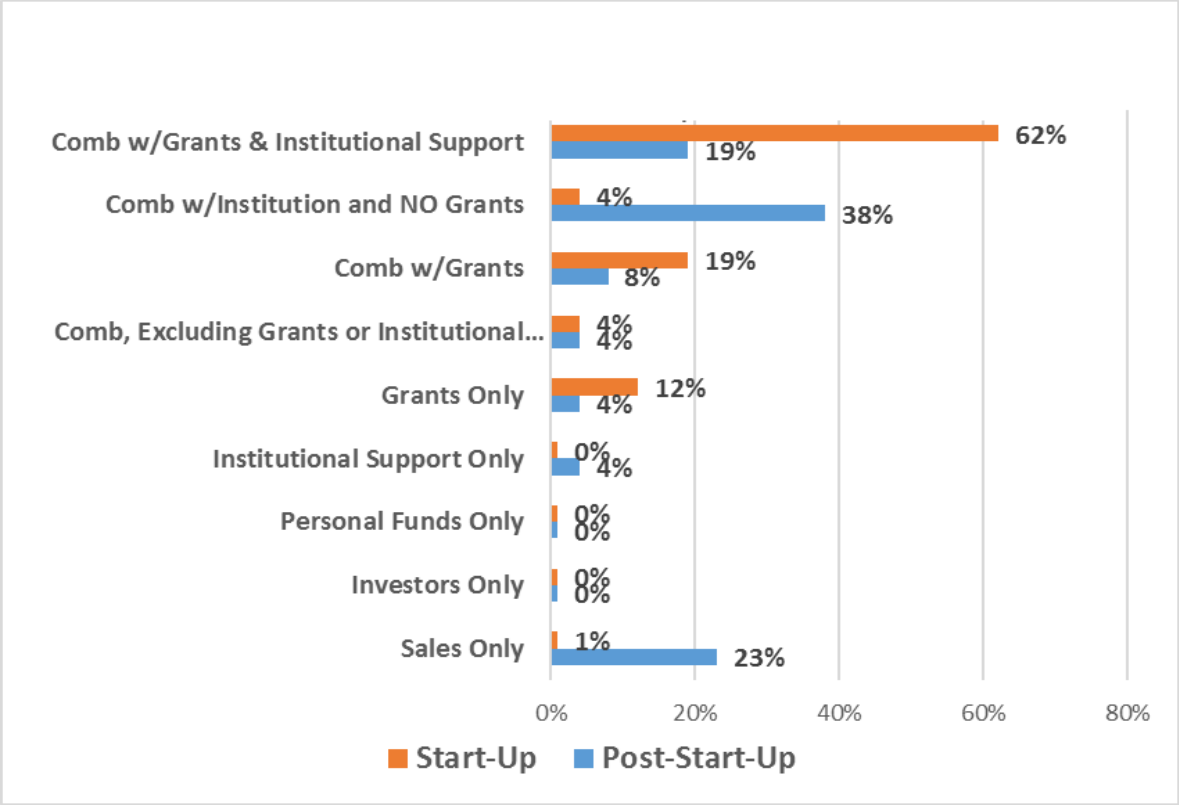
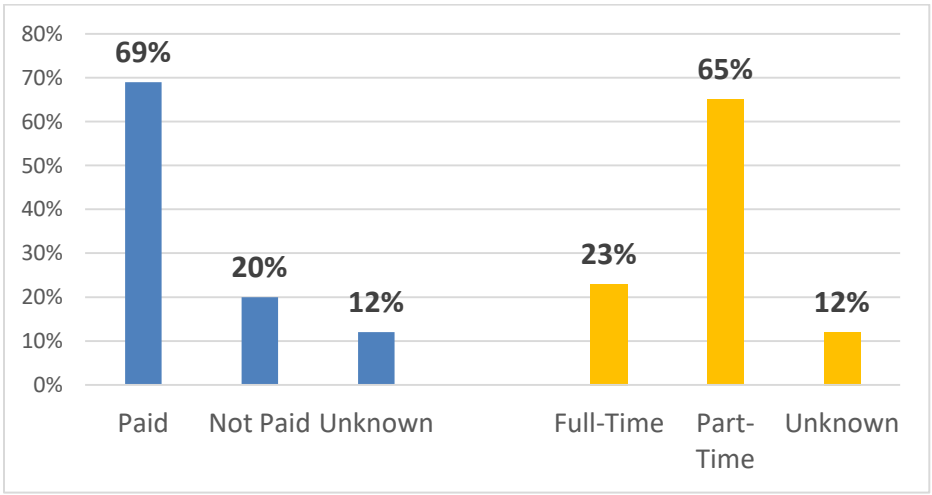


Figure E6: Funding Sources at Start-Up and Anticipated Post Start-U



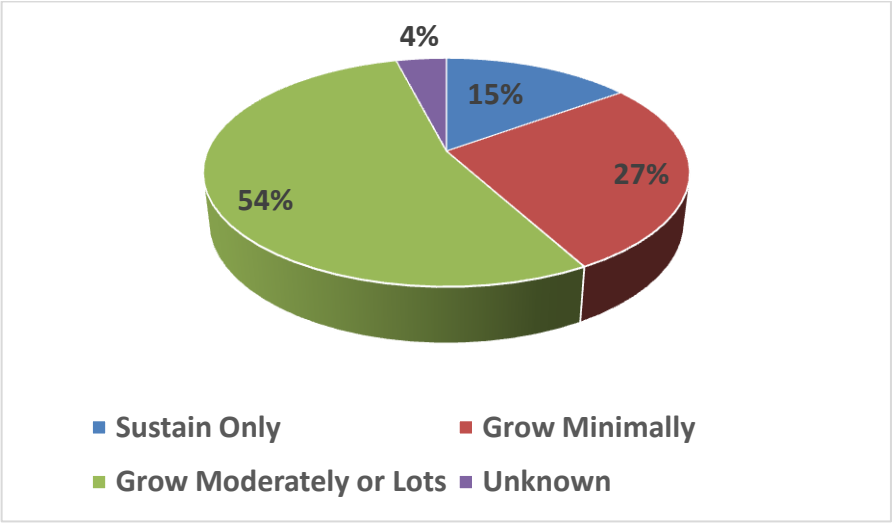
- 93% of innovations rely on grants during Start-Up.
- 31% of innovations anticipate relying on grants after start-up.
- 23% of innovations anticipating relying solely on sales after start-up.
- 61% of innovations (including some companies) anticipate relying on institutional support after start-up.

Figure E7: PI Compensation



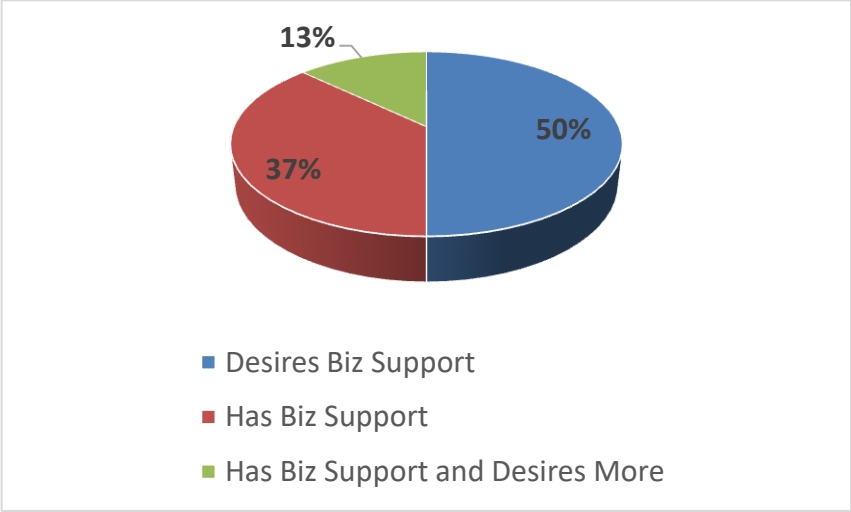
- Most innovators are paid while developing their innovations, mostly due to grant funding and/or institutional support, including salary from their full-time university jobs.

Figure E8: Intention to Grow



- 54% of PIs report intention to scale moderately or lots.

Figure E9: Innovation Business Support



Although this question was not asked directly, comments from 16/26 respondents enabled us to compile this variable.

Crosstabs Analyses

Crosstabs analyses allow us to look at the distribution of responses across two variables. Due to a small sample size, we could not run inferential tests, but several trends are notable and worth further study. Notable findings are shown below.

Table E4: Paid/Not Paid x Full-Time/Part-Time

	Full-Time	Part-Time	Total
Paid	21.7%	56.5%	78.3%
Not Paid	4.3%	17.4%	21.7%
Total	26.1%	73.9%	100%

78% of respondents are paid for their time working on their innovation. 22% work Full-time, 57% work Part-Time. These high rates are mostly due to the fact that innovations are grant-funded.

Table E5: Revenue Flow x Administrative Structure

		Administrative Structure				
		NPO°	CO°	noCO	Co+NPO	Total
Revenue	To CO/Unit	2	2	2	0	6
Flow	To Inst/Org	0	1	16	2	19
Total		2	3	18	2	25*

°NPO=Non Profit Organization; CO=Company

**one case was unknown*

PIs of seven innovations formed some type of company. Revenue flowed directly to the company in 4/7 cases. In the other 3 cases, revenue flowed through the host institution first.

Table E6: Start-Up Funding x Administrative Structure

Start Up Funding	***Administrative Structure***				
	NPO°	**CO°**	**NoCO**	**CO+NPO**	**Total**
Grants Only	3.8%	0	7.7%	0	11.5%
Comb, but no grants and no Inst. Support		3.8%	00	0	3.8%
Comb* w/Grants, no Inst.	3.8%	3.8%	11.5%	0	19.2%
Comb: inst. No grants	0	3.8%	0	0	3.8%
Comb Inst + Grants	0	0	53.8%	7.7%	61.5%
Total	7.7%	11.5%	73.1%	7.7%	100.0%

°NPO=Non Profit Organization; CO=Company

**Comb can include sales, investors, licensing fees, contest winnings, and/or personal funds.*

- 92% (n=24/26) of innovations rely on grants during Start-Up.
- 66% rely on institutional support, even if they are a company.

Table E7: Anticipated Funding at Scale x Administrative Structure

Anticipated Scale Funding	Administrative Structure				
	NPO°	**CO°**	**NoCo**	**CO+NPO**	**Total**
Grants Only			4%		4%
Sales only	4%	8%	12%		23%
Inst. only			4%		4%
Comb, no grant or Inst.			4%		4%
Comb, w/grant	4%		4%		7.7%
Comb, w/institution		4%	31%	4%	38.5%
Comb w/ grants+Inst.			15%	4%	19.2%

°NPO=Non Profit Organization; CO=Company

- At scale, a total of 30% of innovations expect to depend on grant support, compared to 92% during Start-Up.
- 62% foresee continuing to rely on institutional support, compared to 66% during Start-Up.

Table E8: Administrative Structure x Growth Intent

Admin. Str.				
	Unknown	**Sustain Only**	**Grow Minimally**	**Grow Moderately or Lots**
CO°			14%	86%
No CO	5%	21%	32%	42%
Total	4%	15%	27%	54%

° CO=Company

- 56% of innovations overall intend to grow Moderately or Lots.
- 86% of companies (n=6/7) compared to 42% of non-companies expressed an intention to Grow Moderately or Lots.

Table E9: Scale Plan x Administrative Structure

Scale Plan	Administrative Structure		
	CO (any type)	***NoCO***	***Total***
None	14%	21%	19%
Vague	14%	32%	27%
Detailed	14%	11%	12%
Detailed+Shared	57%	37%	42%

- Business Support *correlated moderately (r^2=0.433, p<0.05)) with* Scale Plan. Those with business support were twice as likely to have *Detailed & Shared Scale Plans* compared to those who did not have business support. 83% (n=5/6) of those who *had business support* and 50% (1/2) of those *who had and desired business support* reported having *Detailed or Detailed & Shared* scale plans, whereas *Detailed* or *Detailed and Shared* scale plans were evident in only 38% (3/8) of those who did not have yet *desired* business support. *Also, having business support correlated moderately strongly with* Intention to Grow *(r^2=0.534, p<0.05)).*
- 71% of companies have detailed and/or detailed and shared plans to scale, compared to 48% of non-companies.

Table E10: Scale Plan x Business Support

Scale Plan	Business Support				
	HAS Support	**Desires Support**	**HAS+DESIRES Support**	**Unknown**	**Total**
None	17%	25%		20%	19%
Vague		38%	50%	30%	27%
Detailed				30%	12%
Detailed+Shared	83%	38%	50%	20%	42%

Obstacles & Supports

Common obstacles mentioned by PIs include lack of business experience/support and lack of time to develop an innovation while still managing faculty responsibilities (Teaching and research). One PI talked about the challenge of developing an innovation within the context of the university:

> *It is really hard. When you have grants, you're motivated by different outcomes. You have a plan and deliverables and you report on them. When you enter a business, you need to make money to support that business, and now you have customers, and they have different expectations. They order something and want it shipped out in a day or two. We have a deadline every day. It is different than a grant-run center. It is running two different things…You're running two things which are competing with each other in some respects for my time. …In the grant world, you're looking to make systematic change in the system. Doing something never done before. You get to contemplate and strategize and think about how to best do that. It requires a certain type of brain. When you're selling product, sure you have to innovate the product, but that's a little bit of the work. The rest of the work is you have to buy the inventory, manage the inventory, and manage the people who manage the inventory, the production, shipping, and accounts payable. [These are] very different skills sets. It also means that some of the people, including myself, that are very good strategic thinkers and love to think about a plan and fine-tune it and the big picture and where we'll be in five years, now I have to think about what we're going to do in the next five minutes. We have the students coming in--it's rewarding because you see them learn new skills, build their self-esteem and resumes. But students have finals, spring break, papers to write. They have another life. We have smart people work for us but we don't truly own them.*

There was wide variation across the sample in terms of the environment within universities to support sustaining and scaling of innovations. Some institutions had the experience and infrastructure to encourage these activities, others did not but were supportive, and several institutions were unable to support innovation when it required flexing current infrastructure or implementing alternative means of receiving and/or distributing revenue. There are examples in the data of PIs who switched institutions or left academia to focus on their innovations, but these were rare. Most ICL PIs are primarily committed to their academic jobs and careers, and they value their education and/or social missions over any particular innovation. Therefore, when the environment for innovating is not supportive, these faculty are prone to maintaining faculty activities that are supported by traditional promotion and tenure policies.

8.11 CONCLUSION

We devised the interview protocol based on prior survey and interview data. We believed that the interviews would capture prominent features of each innovation's context and development activities, and they did. However, several of these features are difficult to summarize quantitatively. For example, we asked PIs to quantify their expected growth, based on their definition of "scale." Some, who had specific definitions of "scale," could provide concrete answers. Others responded based on intuition or hope. Projected future growth is relative to current growth. Several respondents projected their income based on sales they had not yet made; pricing or volume of sales could vary significantly from current projections. Gathering specific, reliable data about innovations would require extensive discussions with innovators and, in some cases, their accountants, who would have to provide sensitive information that we could not expect to gather in relatively brief telephone interviews. Also, in several cases we have quantized qualitative data based on PI reflections, resulting in varying reliability of some variables. The relatively small sample size, combined with the level of specificity we could capture in interviews, enables us to describe the context and intentions of innovators post ICL, but hinders our ability to draw inferences or to generalize from these results.

Having noted these limitations, we nevertheless believe that the variables we have distilled from interviews do reveal important insights and patterns relate of ICL innovations that have remained active.

First, grant funding has been integral to nearly all innovations that have developed since ICL. Although ICL participants were exhorted during the training to avoid grant support, grants have supported 92% of respondents, including those who had formed companies and those who hadn't. For many PIs, grant funding provided in-kind support from the institution. The reliance on grants might not be surprising, in light of the fact that ICL, like I-Corps™, is a grant program, eligibility for which depended in most cases on having been awarded prior NSF funds. Many ICL participants are expert grant-getters whose skills can sustain their innovations during start-up. After start-up, however, is a different story. Only 30% expected to rely on grants after start-up.

Second, although ICL participants are encouraged to start companies, the majority will not. It is also notable that in these data, 66% of innovations rely on institutional support during-start-up, and all but one (62%) expect to continue to rely on their institution during sustaining and scaling phases. Included in this group are several PIs who have formed companies. When it comes to learning innovations developed by ICL alumni, distinctions between "company" and "not a company" blur, as was evidenced in the caselets (*Section II*). Some companies continue to operate within or in tandem with PIs' institutions. On the other hand, some innovations that have not formed companies operate relatively independently as units within their institution.

Third, although over half of those we interviewed (54%) intend to scale their innovation *moderately* or *lots*, several are hindered by lack of business experience and/or support. ICL alumni often admitted that innovation development was stymied by their lack of business acumen and/or access to those who have

it. We see having business support or not as a potentially critical variable in the successful development of learning innovations. Business support was greatly valued when it occurred and often desired when it had not. Nearly all PIs who had access to business expertise also had specific and shared scale plans and intended to grow *moderately* or *a lot*. Some who had business support desired more. Having a scale plan that is detailed and shared seemed a distinguishing factor across the innovations.

Further research would be required to discern whether having business support causes teams to develop specific and shared plans for scaling, or whether intending to scale causes PIs to seek business support. What we can say is that those who had business support were sometimes effusive on the value of that expertise. PIs that formed companies reported that they were often required to create scale plans for investors and other funders and stakeholders. On the other hand, a few innovators recognized that they were stuck—they didn't know what to do next. In other cases, it was obvious that an innovation could benefit from an expert, such as guidance from a mentor or incubator.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 OVERVIEW

The objectives of the study were to:

1. Understand and document the outcomes for the ICL innovations with respect to scaling and sustainability
2. Understand and document if and how the participating team members apply what they learned through ICL
3. Identify and define the start-up ecosystem in which ICL innovations scale and sustain.

This work was guided by two overarching questions designed to address the targeted ICL outcomes.

1. What are the outcomes of participation in ICL on the teams' innovations, the team members' personal and professional development?
2. What are the key features of and pathways within the ecosystem(s) in which ICL team members seek to successfully scale and sustain their STEM education-related innovations?

The ICL study produced a rich data set in which information about the teams, the status of the innovations, the individual impacts, and the challenges and opportunities faced have been explored. These findings are presented with an appreciation that the variations in the experience and progress of teams are complex. For example,

- The make-up of the teams in each cohort differed based on the pool of applicants, resulting in variations in innovation maturity and history of funding. This history may have had an impact on the extent to which an innovation had been developed and tested and how much time and attention the team members had devoted to the innovation.
- Within a team, there is variation on the roles of the individuals; PIs are often faculty members and ELs professional roles varied, though often the ELs were program professionals who have built a career on soft-money grants. Motivations of team members may also have had an impact, as members may have joined with the intention of commercializing, or may have joined looking to scale and/or sustain their innovation in the context of their current profession.
- The experience in the course may have had an effect on teams. The first cohort of ICL participants went through a format that was more "relentlessly direct" than cohorts 2 and 3 in which the teaching team modified their tenor. Another notable difference is the time at which the course was offered. For those in Cohort 1, they participated in the course and then had a summer during which they could focus on the innovation. Cohorts 2 and 3 completed the course just before beginning an academic year. Likewise, the NSF grant cycle often has a spring submission schedule, meaning Cohort 1 may have had to wait longer than cohort 2 before applying for NSF grant funds.
- The post-course context has a profound impact on how successful a team is in scaling and/or sustaining and/or commercializing their innovations. The ecosystem in which educational

innovations operate is highly complex. This study, particularly the interviews, began to surface a range of opportunities and challenges faced by the teams.

We offer three overarching takeaways related to the research questions:

1. *Sustaining* versus *Scaling is an important distinction for ICL participants.* ICL faculty and program leaders emphasize the importance of "sustaining and scaling innovations." The phrase is intended to represent a sequential process. Yet to many PIs we interviewed, sustaining an innovation is not seen as a pre-condition of scaling. In the minds of those we interviewed, making an innovation self-sustaining was a worthy goal, one rarely achieved by grantees. Making an innovation self-sustaining would be considered a success by these PIs, if doing so yielded perpetual benefits to individuals and institutions that are comparable to those achieved through three- or five-year grant awards. If an NSF program goal is to extend the value of initial grant funding, perpetual sustaining of a grant-funded innovation meets this goal, as long as the program is not sustained through federal grants.
2. *Whether teams seek to simply sustain their innovation beyond grant funding or whether they seek to scale broadly, ICL was a valued as a stepping stone to success.* As noted in the report, nearly all active teams with customers attributed some to much of their success to ICL. This longitudinal study as well as QED cohort evaluations have documented significant shifts in the attitudes and behaviors of ICL participants, whose entrepreneurial alter-egos have blossomed as a result of exposure to program concepts and customer discovery. Most comments overall about ICL were extremely positive; PIs spoke about how the experience has changed how they think about designing education-related products, programs, and/or services. Most participants had little commercialization experience prior to ICL. The program changed their thinking about what they do and how they do it, causing many to apply an entrepreneurial mindset to their research that sparked them to continue developing their innovations beyond initial grant funding.
3. *ICL training is a necessary but insufficient vehicle by which to promote either sustaining or scaling of NSF innovations.* Both in spite of and because of the transformation towards an entrepreneurial mindset, some PIs felt let down by NSF due to lack of follow-up support after ICL. Sample quotes include:

> *Seeing as the NSF invested $50,000 in us - we feel orphaned. They said "Here's the money, good luck. Don't blow it all in one place" and left us on the bridge to nowhere.*
>
> *Either ICL needs to be reformatted or a new program needs to be announced as a sort of follow-on program. My sense is that we came through this program and they said "go do all your research" and then we got abandoned. What we need is some actual hands-on, startup help. My takeaway is that the ICL process was interesting but not enough and I'm wondering if other teams felt the same way.*

The remainder of this section is dedicated to describing the main results of each component of this analysis.

9.2 TEAMS

Most teams were still active at the time they took the first survey (~7-11 months post-training) and three quarters were active at the second administration (~19-24 months post-training).

Teams came to the ICL course with innovations in various stages of development. Some teams had a well-tested innovation while others selected a project for the purposes of participation in the course. Surprisingly, 28% of the ICL teams did not include a member that had been a PI or co-PI on a pre-ICL NSF award based on a search of NSF Awards. That said, the amount of pre-I-Corps-L funding does appear to be a factor in predicting the subsequent progress of the teams, with 60% of those teams making most progress having had $300,000 or more of prior funding. The NSF funding source is important, as continuous funding seems to be important for successfully advancing the innovation (Though lack of funding didn't mean a team was not progressing) and for some teams, obtaining new NSF funding was seen as the best means of scaling their innovation and sustaining their teams.

The greatest barriers were consistently related to lack of financial and human resources. The analysis shows that though most of the PIs were involved over the life of this study, along with continuous funding, the sustained involvement of the EL made a difference for how successful a team was.

As the innovations were advanced, most teams stayed in an academic setting, even if they anticipated shifting to a new structure. That said, the most active teams at T2 had increased levels of problems associated with their home institutions. Most teams (69%) at T1 say that their innovation is both a product and a service. At T2 the teams showing the most activity and progress were most likely to be supporting a service or program-oriented innovation. This may be due to the greater likelihood of grant funding for services and programs. Similarly, at T1 teams were equal in having higher education and K12 markets. By T2, the active teams were more likely to be in K-12. It is unclear how, if at all, the relationship with the academic institution helped or hindered securing grants and/or working in a K-12 environment.

The Post-ICL funding is indicative of both continued effort associated with innovations associated with prior funding and new funding that may be not be associated with the ICL team's innovations. For some teams, obtaining new NSF funding was seen as the best means of sustaining their innovation.

9.3 INDIVIDUALS

The ICL program had an impact on individuals and the participants were favorable about the program. The effects of ICL were seen mostly through participants developing entrepreneurial mindsets and not in a new career path. In general, the participants in ICL are often have a STEM research background and have moved into education, often via grant funding from NSF. Most faculty are inexperienced in

business or law, particularly as it relates to commercialization of a business venture. The participants are not looking to move out of their current professions; rather, they turn to ICL looking to sustain and/or scale their educational innovations. This corresponds to the general tendencies of the team-level analysis.

9.4 Institutional Overview

The study relies on self-reports from participants and did not collect data from administrators or other representatives at the home institutions. Survey responses suggest that the ICL impact at an institution is more pronounced on a faculty basis than institution-wide. When discussing the impact on faculty, most report the integration of entrepreneurship or an entrepreneurial mindset being brought into the classroom. There are unique instances in which faculty did influence the institution, for example, forcing an institution to address intellectual property (IP), accommodating a revenue-generating enterprise and, accommodating faculty pursuing the commercialization of research products.

9.5 Mentors

Each team had a mentor that participated in the course, offered guidance, and may have conducted customer discovery interviews. Most mentors were not entrepreneurs and lacked experience in the educational ecosystem; thus, they were not appreciably different than the PIs and ELs in their background in customer discovery, the task for which they were providing primary support. It is possible they had skills and expertise that was untapped given the structure of the ICL course. Mentor experience or job status did not appreciably affect ICL and/or innovation outcomes, even when mentors were entrepreneurs. Despite the variance in the selection, engagement, and maximization of mentor expertise, there is an overall positive attitude towards ICL as a process for moving an innovation forward and as a learning experience on behalf of the mentors. A deep dive into the mentor data revealed three archetypes:

The Mentor: The mentor was typically someone who had business and legal knowledge related to scaling or sustaining an innovation, may have had experience as an entrepreneur or investor or other business experience. The Mentor provided advice and guidance, helped interpret findings from the customer discovery interviews and interpret the feedback from the teaching team.

The Team member: Mentors in this archetype acted as team members. This group brought the least amount of experience prior to the course, particularly lacking prior experience in the Business Model Canvas and Customer Discovery. These team members often conducted a significant portion of the customer discovery interviews (more likely in Cohort 2) and served as cheerleaders rather than advisors.

The Mentor-Team member: Mentor-team members are typically deeply involved with the team; all mentor-team members were involved with the innovation in the six months prior to the ICL course in a mentor relationship and ICL allowed them to continue this relationship. These mentor-team members draw upon their business and legal knowledge and experience to guide the team.

9.6 Retrospective Course Feedback

The participants who found the training to be very or extremely valuable credit the ICL process to be a catalyst for advancing their innovation. Without ICL, the team would not have been as focused, the project would not scale as quickly or to the market as expected and/or been as efficient of a process. These participants also report that their entrepreneurial mindset has influenced subsequent projects and teaching.

9.7 Interview Study: Team Motivations, Intentions, Supports, and Obstacles

The interviews conducted with the ICL participants confirm the findings above, highlighting several key themes. First, grant funding has been integral to most of the innovations that have developed since ICL. Although ICL participants were exhorted during the training to avoid grant support, grants have supported 92% of interview respondents, including those who had formed companies and those who hadn't. For many PIs, grant funding provided in-kind support from the institution. The reliance on grants might not be surprising, in light of the fact that ICL, like I-Corps™, is a grant program, eligibility for which depended in most cases on having been awarded prior NSF funds. Many ICL participants are experienced grant-getters whose skills can sustain their innovations during start-up. After start-up, however, is a different story. Only 30% of interviewees expected to rely on grants after start-up.

Second, although ICL participants are encouraged to start companies, the majority will not. It is also notable that in the interview data, two-thirds of innovations rely on institutional support during-start-up, and all but one expect to continue to rely on their institution during sustaining and scaling phases. Included in this group are several PIs who have formed companies. When it comes to learning innovations developed by ICL alumni, distinctions between "company" and "not a company" blur, as was evidenced in the "caselets". Some companies continue to operate within or in tandem with PIs' institutions. On the other hand, some innovations that have not formed companies operate relatively independently as units within their institution.

Third, although over half of those we interviewed (54%) intend to scale their innovation *moderately* or *lots*, several are hindered by lack of business experience and/or support. ICL alumni often admitted that innovation development was stymied by their lack of business acumen and/or access to those who have it. We see having business support or not as a potentially critical variable in the successful development of learning innovations. Business support was greatly valued when it occurred and often desired when it had not. Nearly all PIs who had access to business expertise also had specific and shared scale plans and intended to grow *moderately* or *a lot*. Some who had business support desired more. Having a scale plan that is detailed and shared seemed a distinguishing factor across the innovations.

Effective customer discovery—the focus of ICL—is only the first step to effectively scaling an innovation, and most alumni lack the expertise or access to necessary expertise to move viable innovations towards commercialization. ICL provides the knowledge and motivation to conduct customer discovery, but many who discover promise in their innovations require further business/operational knowledge and

expertise beyond those involved with customer discovery. ICL innovators struggle with the issues such as:

- Pursuing innovation development while managing academic responsibilities;
- Defining scale and developing effective strategic plans; sometimes this boils down to simply identifying the right priorities at the right time;
- Navigating complicated institutional and/or inter-organizational policies and procedures;
- Keeping sufficient records, including balancing the books, especially when innovation funding and/or revenue flow to multiple institutions.

9.8 RECOMMENDATIONS FOR THE ICL PROGRAM

***Beyond Customer Discovery*:** ICL focused almost entirely on customer discovery. While the Business Model Canvas (BMC) was explained, most of the faculty's and teams' effort was focused on identifying and aligning value propositions and customer segments. Success leads most teams to advance their innovation. These teams would benefit from a follow-on program that focused on strategies for sounding the completed BMC, gathering evidence of the BMC viability through sales and/or follow-on grants, and scaling an innovation. An advanced course could also cover navigating opportunities and challenges within the host institution and other common issues that face education innovation development.

Entrepreneurial Lead: The role of the EL appears to be critical to the continued progress of the innovation. Given that most PIs show little inclination to significantly change their career path, it may be more critical encourage teams to have an EL that embraces the potential opportunities that advances in the innovation may offer.

Mentor Model: The ICL model of one mentor per team, typically selected by the project team, may not be the most effective approach. There is no evidence that the mentor model significantly contributed to the development of the innovation or the sustainability and/or scalability of the innovation. Mentors were valued by team members and seen as important, yet there is no correlation between mentor involvement and project success. In some cases, the mentor was going through the BMC process for the first time; others came with limited business and legal knowledge but did have experience with the underlying science of the innovation; some mentors had entrepreneurial experience but lacked the educational context which a team needed. The role mentors played on a team also varied, with some acting as an additional team member, and others balancing both mentorship and team membership. Given the variation in background and experience, the ICL study team recommends that ICL program develop a set of mentors that can work as advisors across projects. Ideally, these mentors will be available to the project teams for a period of time after the course as they attempt to scale and/or sustain.

Better engagement of the host institutions: Based on these results, conversations between ICL Teams and their host institutions appear to have been very limited. Many of the teams don't match the profile of technical innovations that universities are learning how to support. As such, more dialogue needs to

be encouraged at the time of application and through the ICL process that helps team understand what support might be available or needed from their host institution and in turn for the host institutions to understand what support is needed by the team.

Create New Funding Opportunities for Education Innovations: NSF can foster innovation in the education ecosystem through a program that parallels SBIR and STTR through an Education Innovation Research program. PIs could use data from customer discovery and subsequent activity to generate new output research related to innovating in the education ecosystem, which is typically characterized by a) having no IP and b) working within an institution (intrepreneurship). Such a program would align with Research Types 3, 4 & 5 of Common Guidelines for Education Research & Development:[19]

- Research Type 3: Design & Development Research
- Research Type 4: Efficacy Research
- Research Type 5: Effectiveness Research

An Education Innovation Research program would constitute scale-up research that would explore the little-known and understood education ecosystem, which could have broad impacts across higher education: *"Efficacy, Effectiveness, and Scale-up Research contributes to evidence of impact, generating reliable estimates of the ability of a fully-developed intervention or strategy to achieve its intended outcomes."*[20]

9.10 RECOMMENDATIONS FOR FURTHER STUDY

This study provides a rich data set and a strong foundation for which to understand the ICL program as a process for supporting NSF PIs in scaling, sustaining and/or commercializing a learning innovation. There are, however, questions that have emerged during this study that warrant further exploration.

Originally, the ICL Longitudinal Research Team sought to characterize the ecosystems within which ICL innovations sustain and scale. We learned early on that operationalizing *ecosystem* would involve extensive study of individual innovations that could not be supported by the funding and timeline of the current evaluation. Instead, we shifted our focus to the precursors of ecosystem; that is, the motivations, intentions, supports, and obstacles that shape the innovation and its users, and the administrative structure and environment within which it is situated. We believe that the factors identified in this study provide a basis for a deeper dive into how motivations for and intentions to sustain and scale influence innovation development and the ecosystems within which they survive and thrive.

The full extent of the ecosystem in which ICL teams are scaling and/or sustaining their innovation is still not well understood. It is so complex and multifaceted, the work required falls outside the bounds of this study. That said, this study does provide the precursor to a study of ecosystem by helping to define the elements that contribute to understanding the environment in which ICL teams are operating.

[19] Common Guidelines for Education Research & Development, NSF 13-126
[20] Ibid., p. 9

Additional topics of particular interest of further study are:

- The differences between innovations seeking to scale and/or sustain when providing an innovation targeted to higher education versus the K-12 environment. This study found those in K-12 were more likely to remain active though it is unclear if it is due to the nature of the innovation, the availability of grant support, features of the ecosystem such as market channels or other variables.
- The impact of ICL teams seeking to sustain and/or scale on the home institutions, and the institutional context's impact on their ability to sustain and/or scale is still not well understood. Further study is recommended to understand how the institutions affect ICL teams and their success, and how the ICL teams affect the institutions.
- Further research would be required to discern whether having business support causes teams to develop specific and shared plans for scaling, or whether intending to scale causes PIs to seek business support. What we can say is that those who had business support were sometimes effusive on the value of that expertise. PIs that formed companies reported that they were often required to create scale plans for investors and other funders and stakeholders. On the other hand, a few innovators recognized that they were stuck—they didn't know what to do next. In other cases, it was obvious that an innovation could benefit from an expert, such as guidance from a mentor or incubator.
- EL activity is highly correlated with the activity level of each team, but it is difficult to determine the direction of causality; ELs may only stay involved in ICL if the innovation appears to be making progress, but they could also be a significant source of momentum. As mentioned elsewhere in this report, ICL ELs are distinct from the comparable role in the canonical I-Corps™, and further study is required in order to understand the unique role they play on ICL teams.
- Many individual participants indicated that even though their career did not change, the way they accomplish their day-to-day duties has evolved substantially to incorporate the training of ICL and the entrepreneurial mindset it emphasizes. More information on the impact of ICL training outside of the innovations themselves would be useful in evaluating the impact of ICL at a more holistic level.
- Ultimately, this research would benefit by being able to consider a various set of control groups. These could be in terms of the modality of support focused on scaling and sustainability experienced by ICL (based on LeanLaunch Pad). One could also consider the advancement of NSF funded educational innovations to better understand why some scale and/or are sustained while others don't. Finally, a comparison could be conducted focused on the participants to see if their growth in entrepreneurial mindset changes as a consequence of this intervention more or less than others that are offered.

We appreciated the opportunity to study the longitudinal consequences of this NSF program as a research grant. In contrast to a contracted program evaluation, which we have had the privilege of being part of, the research grant permitted greater flexibility in responding to early findings and discussions with stakeholders. We also experienced the challenges of a two-year time constraint associated with studying multiple cohorts, especially given that one of which started within the period of this grant. Not surprising, longitudinal studies take more time to observe the full scope of outcomes.