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Progression By Imitation: Empirical Evidence From The NTNU–CERN Screening Week

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ABSTRACT

Engineering students should work on authentic and ‘wicked’ challenges to be best prepared for developing technologies that address challenges in our complex world. This can be done with a learning-by-doing approach where students are positioned as entrepreneurs exploring market opportunities for novel technologies. During the NTNU–CERN Screening Week, students in an entrepreneurship program search for and create opportunities based on technologies developed at CERN that may have the potential to later become a start-up. However, the students have limited domain knowledge in terms of the advanced technologies or industrial application of them. Also, the technology readiness level (TRL) of the presented CERN technologies is often far from potential market entry. Previous research has primarily considered how student-oriented programs for technology commercialization are organized. In the present paper, we ask how students proceed to successfully generate market insights

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for progressing in a technology commercialization process. We performed an empirical process study of five student-driven feasibility studies. Our data includes in-depth interviews, field notes and on-site observations. The data is systematically analysed according to the visual mapping protocol for robustness and reliability. Our findings demonstrate how the students are translating an immature technology into a higher TRL and envision applications that do not exist in the real world, to be able to initiate conversations with potential customers and users. These insights contribute to the understanding of how students are becoming 'great pretenders' or 'breaking the norms' to engage stakeholders and enter the ‘Promoters Dilemma’, also challenging existing norms.

1 INTRODUCTION

This study investigates how students generate market insights into novel technologies for progression during their feasibility study. The feasibility study focuses on realizing technological potential and matching technological developments with specific applications and needs (Harris and Harris, 2004). Training students on the market identification of potential use cases of novel technologies is essential for several reasons. First, students could bridge technology novelty and the market by identifying unmet market problems and ways to serve customers' needs (Barr et al., 2009). Secondly, students can be intermediaries between the technology provider and potential market actors (Neck and Liu, 2021, Hellmann, 2007). They provide researchers with essential market insights on potential use cases of novel technologies (Giones et al., 2021) and market acceptance. Third, conducting a feasibility study is also a potential starting point for developing new business ideas and later launching new technology-based ventures (Lahikainen et al., 2022, Neck et al., 2021). A feasibility study also equips students with market knowledge of technology development and a better insight into the innovation process (Klofsten et al., 2020), which is deemed vital for their careers.

Previous research has considered technology commercialization educational programs where students are the main actors in the process (Neck and Liu, 2021). Kaspersen and Aaboen (2021) describe how students are doing feasibility studies on novel technologies developed at the European Organization for Nuclear Research (CERN). The student-driven technology commercialization program is one of CERN’s initiatives for societal contributions from knowledge transfer activities (Nilsen and Anelli, 2016). During the feasibility study, students gain new knowledge of market assessment and ideation simultaneously– obtained through actions and interactions with potential stakeholders (Haneberg, 2020). Thanks to the new insights and interdisciplinary discussion among different actors, students develop ideas of new applications with higher commercial and technology readiness (Markham, 2016). Students, therefore, explore new fields of technological applications – which are potentially overlooked by scientists (Åstebro et al., 2012). However, defining such market needs for novel technologies is challenging because of low level of technology readiness and uncertainty in terms of market acceptance (Stinchcombe, 1965). Moreover, students cannot search all possible technology-market fits due to limited resources (i.e., time) and knowledge domain (Andries et al., 2021).

Nevertheless, the literature has not yet identified how students obtain new insights through engagement with different stakeholders during the feasibility study - given that students have limited adequate social networks and lack professional networks. This study, therefore, focuses on the question “How do students generate market insights of novel technologies during a feasibility study?”. To answer the research question, this paper is structured with an introduction, followed by a conceptual framework of students as imitative entrepreneurs. Using a qualitative approach, the paper then presents findings of how students develop imagined new venture ideas based on market insights and their progression by imitating experts.

The study builds on the theoretical framework of knowledge development through imitation (Meltzoff and Decety, 2003) by offering new insight into how students mimic and pretend to be experts to obtain market insights of novel technologies. The study also contributes to engineering education by offering new insights into teaching approach that emphasizes action-oriented and learning by doing through imitation.

2 THEORETICAL BACKGROUND

To commercialize novel technologies, students – playing a mediating role between the enactors (technology providers) and selectors (technology users) (Bakker and Budde, 2012) – often gather different inputs and feedback from broad stakeholders, potential customers, and users. Students also deal with information asymmetry (Balakrishnan and Koza, 1993) on the "future values" of the novel technologies in the presence of fundamental uncertainty and ambiguity (van Lente et al., 2013). To overcome uncertainty, students search across knowledge domains to identify "connectors" – or people who have experiences and knowledge of the fields they lack (Van de Ven, 2017, Gavetti and Levinthal, 2000). New knowledge is also obtained through interactions and observations (Politis, 2005, Leyden et al., 2014). Given a limited social capital resource, students cannot find relevant people in a short amount of time during their studies. Instead, students get in touch with people they are already familiar with within their network (i.e., through close network search) (Aldrich and Kim, 2007) and apply the snowballing approach to expand their network. To engage with people, students need to explain the novel technologies to different actors using the experimental-experiential process of an iterative process to test market response to the novel technologies and their ideas (Haneberg, 2019).

To envision new applications of novel technologies, students build their "imagined future venture ideas" (Davidsson, 2015, p.683), engaging with stakeholders to attract attention to their ideas. They function as "imitative entrepreneurs" for the diffusion of new technologies (Hannafey, 2003) – which are immature and low in technology readiness level for market entry. During these engagements, students enter the "promoters dilemma" of trying to learn new knowledge to build higher, more mature technology applications while promoting claims based on how their "visions" of the future applications for the technologies. To a certain extent, those claims hinder future technological competencies that do not exist yet in the real world, thus, prompting an ethical dilemma on the real and artificial values of the technologies being promoted. Importantly, students might find themselves in the hype cycle of *"early promises, late disappointment"* – the early stages of novel technology trigger optimistic and exaggerated expectations (van Lente et al., 2013) following a high degree of enthusiasm, excitement, and unambiguity on the real and artificial values of novelty.

Gathering market insights starts with proactively searching and identifying potential market actors, customers, and users to obtain knowledge of the commercial potential. It follows their own assessment and validations of the technology-market fit identification (Andries et al., 2021, Gruber et al., 2013). In doing so, they constantly readjust their choices of market (Gruber et al., 2008) and further develop ideas on new applications of novel technologies – based on the feedback they obtain from external stakeholders. In this case, students pretend that they possess knowledge regarding technology novelty while having limited domain knowledge– imitating experts in the knowledge domain. In doing so, they gather interest and attention from diverse stakeholders in the field (Hannafey, 2003). They keep doing so to an extent that they can initiate conversations and discussions with experts while still grasping new knowledge. To sum up, the process of generating market insights is an iterative and double-loop process of assimilation and acquisition of new knowledge from social interactions, whereas new knowledge is obtained through imitation.

3 METHODOLOGY

3.1 Case selection

We followed a cohort of 39 students in their 1st year of a Venture Creation Programme (VCP) in Norway. The students were members of five student teams. They were introduced to five novel technologies selected based on the following criteria:

- The availability of technology experts
- The novelty and commercial potential for start-ups
- Technology readiness for commercialization

A summary of the process of the NTNU Screen Week is illustrated in Figure 1 below:

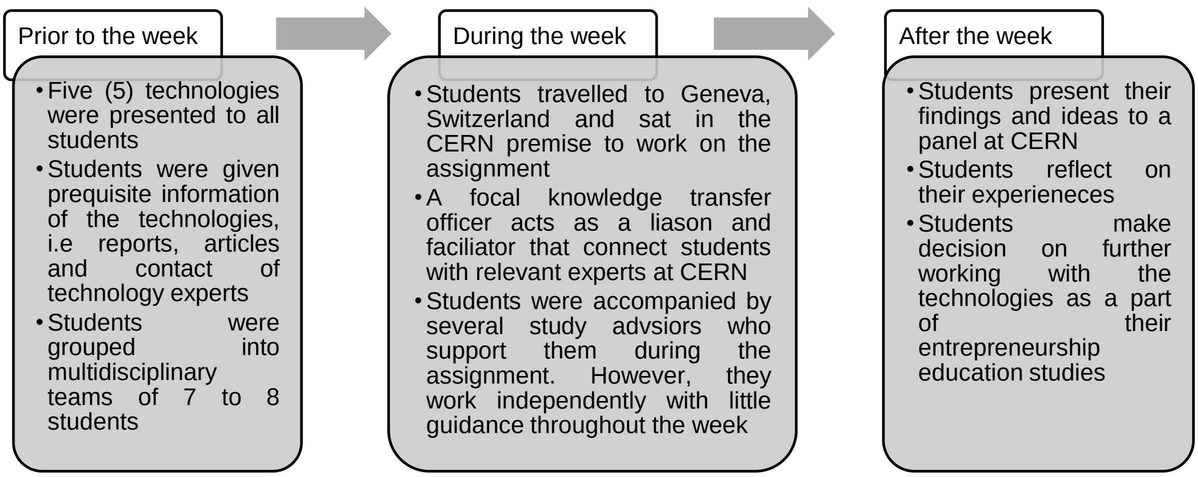

Figure 1: NTNU Screening Week

All the technologies were developed at CERN for fundamental particle physics research; thus, they are considered novel technologies. They require subject-matter knowledge in understanding how they work. In addition, the technologies are generic, far from the market, and in the early stage of commercialization and thus low in terms of technology readiness level (TRL). In addition, the potential technology-market fits are relatively unknown, which deems to be challenging and highly uncertain for students during the feasibility study. The five technologies are included in the Table 1 below.

Table 1: Technologies offered during NTNU Screening Week

Technologies	Team	Technology description
Ultralight Cold plate	UCP	The cooling of power dissipating elements, based on micro-macro vascular pipes embedded in high thermal conductive carbon substrate. It is made of a high thermal conductivity carbon plate, embedding ultralight polyimide cooling pipes

Rucio	RCO	A distributed data management system, which is a system that is designed to access and view a collection of physically separate data storages as one single data storage.
Structured Laser Beam	SLB	A low-cost laser that produces a non-diffractive beam (NDB) that has very low diverge and can maintain the Bessel-like beam and spot sizes for long distances.
Qubik Laser	QLR	A singular light laser developed by CERN and Macquarie University, Australia. It is a simple, efficient, and agile multi-mode to single mode converter in the difficult visible spectrum of 450 nm - 530 nm
White Rabbit	WRT	A fully deterministic ethernet-based network for general purpose data transfer and synchronization. It can synchronize over 1000 nodes with sub-ns accuracy over fibre lengths of up to 10 km

3.2 Data collection

Data was collected through focus-grouped interviews with five students' teams, which utilizes the reflections of the whole team rather than individuals. A total of 70 pages of primary data from interviews and 161 pages of secondary data from students' reports. The primary literature helps us in defining the interview guides. In addition, some reports from previous years and reflections from the university advisors who were actively involved in the process previously have proven are useful reflections on students' behaviours during the feasibility study. To avoid biases and facilitating the process of open discussion, we continued to alter the interview guide with questions (Corbin and Strauss, 2015) as the interview were progressing. The summary of data collection is described in Table 2 below.

Table 2: Data collection

Teams	**Primary data**	**Transcripts of primary data**	**Secondary data (time log of conversations between each team and external actors)**
UCP	2 interviews with each team before and after the week with notes and observations during the week.	12 pages	35 pages
RCO		18 pages	47 pages
SLB		14 pages	24 pages
QLR		12 pages	32 pages
WRT		14 pages	23 pages
Total	**10 interviews**	**70 pages**	**161 pages**

3.3 Data analysis

All transcripts were imported into NVivo software version 10 to conduct inductive thematic analysis through an open coding (Corbin and Strauss, 2015).

First, the sense-making approach was made initially using visual mapping strategy (Langley, 1999) with key anchors of different market insights students gather and from which people that give them those insights, which are drawn from the secondary data as well as interviews. We apply method of critical incidents techniques (CIT) and consider market insights (incidents) as units of analysis (Flanagan, 1954, Bott and Tourish, 2016). We then conducted a within-case analysis (Eisenhardt, 1989) by looking into each team case from both interviews and reports to gain an in-depth understanding of students' processes. A team of four (4) researchers discussed the mapping of this process and illustrated how students make progress throughout the week.

Next, we found patterns among five (5) cases, and labelled them as empirical patterns (Gehman et al., 2018) – which are presented in Figure 2. The use of CIT techniques emphasizes the importance of gathering market insights events in a parallel process of ideas development (Cope and Watts, 2000). Specifically, this method allows us to see how students gather insights and categorize their behaviours during ideation processes. In addition, the visual mapping strategy offer in-depth views on how different processes occur over time.

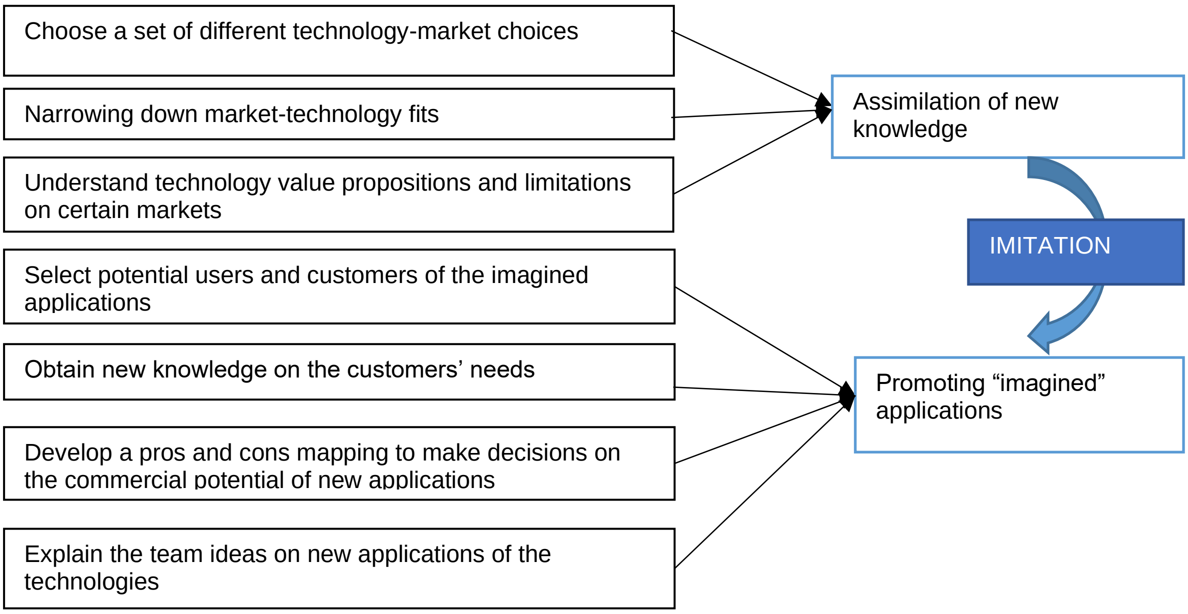

Figure 2: Coding tree structure on the process of gathering market

4 RESULTS

In this section, we present the process of how students generate markets insights of novel technologies and how those insights shape students' progress of technology development. We then discuss on how they make progress of technology development by imitating experts to gain new market insights from other people. We summarize our results with a conceptual framework of progression by imitation (Figure 3).

4.1 The imagination of new venture ideas

Table 3: Markets insights and students' progression during feasibility study

Market insights gathered by students 'teams	**Progression in students' idea development**	**Dimensions**
Insights from current technology development	Choose a set of different technology-market choices	Assimilation of new knowledge
Insights from the close network of experts (i.e., professors, alumni students)	Narrow down technology-market fits	
Practical insights on the chosen markets (from market actors)	Understand technology value propositions and limitations on certain markets	
Insights on the whom finds the technologies useful	Select potential users and customers of the imagined applications	Promoting "imagined" applications
Insights on the needs of potential customers	Obtain new knowledge on the customers' needs	
Insights on how realistic the ideas are	Develop a pros and cons mapping to make decisions on the commercial potential of new applications	
Insights on how the market functions	Explain the team ideas on new applications of the technologies	

Table 3 describes the process of the students' teams in developing imagined applications of novel technologies and the critical market insights that support them in developing their ideas. In detail, students' idea development was progressing in parallel with process of gathering different critical market insights. Those insights are, in turn, help students 'teams shape their ideas of technology development and imagined applications of novel technologies. The process of generating market insights starts with students' search process of looking into different market choices for novel technologies. Students are suggested the market applications by experts who work closely with the inventions and possess deep technical knowledge. Students continue to discuss with people in their close network, i.e., alumni students and university professors, and receive some directions on how they should progress further with the cases and relevant actors they should contact. Students use their alertness and their knowledge (Fiet, 2007) to identify new opportunities in the technologies and narrow down the fits between technologies and the markets while conducting both random and "small world search" (Aldrich and Kim, 2007) to obtain new knowledge on the demands and customers' needs.

Assimilation of new knowledge

In detail, students engage in conversations with actors knowledgeable about the field – they try to explain how the technologies work, their limitations, and their unique values. Students establish different market choice sets of how technologies could be applied and assess different markets of novel technologies. To identify those market opportunities, students contact relevant actors in various industries, and they rely on "connection actors" (Zahra and George, 2002) who act as a bridge in introducing students to relevant people offering insights into how the market works and the feasibility of how the technologies could be implemented into one market. These connections could be researchers, technology experts, market actors, etc. As the feasibility study is conducted in an educational context, the primary relationship that introduces students to new knowledge fields are researchers at research institutions.

> *"Researchers. We made our thoughts on how you can fit this product into other markets, but we just mainly talk to researchers."*

The assimilation of new knowledge is the process of students learning different understandings related to the technologies, markets, and constantly absorbing new knowledge. The validation of different market sets could heavily rely on their ability to know "which information to search" and "whom to search" based on the team's knowledge of the technologies.

> *"So now you can take your time getting some thoughts on who you should ask and what you should ask them. So maybe ten people you call will give more valuable information than a hundred. So, it's part of the learning process."*

Promoting "imaged" applications

Students develop new ideas for market applications from novel technologies based on the external responses of different actors and the internal team discussion. This is an iterative process based on their ability to understand the technology and identify relevant and important market actors.

> *"It's very iterative, a combination of luck and routine."*

> *"You sort of need to connect the dots between technology and how this can be transferred for our idea and business model. That can be very difficult, I think, especially in the beginning, you just ask these open questions, and you don't get deep enough to get some value out of the questions. But now I feel that it's more quality over quantity now than in the beginning."*

Students could identify several relevant market actors who show interest and offer insights into the potential application fields. They could be able to narrow down the market and continue to find essential actors who offer how the technology could be developed further.

> *"We understood that in this market, weight is extremely important. And the weight of the ultra-light cooling plates is ultra-light. And we also understood that cooling is a big issue in that market. Sometimes people have to turn the satellites completely off to cool them down. And we thought that if the plates of the cooling systems can be light, that will be great for that market"*

In the context of technology novelty when the market does not yet exist, students engage in conversations to promote their ideas while having limited knowledge of technology probe two main challenges. On the one hand, students quickly build up their competencies regarding the technology and can obtain new knowledge quickly. On the other hand, students might potentially enter a "promoter dilemma" while promoting their ideas. In particulate, this dilemma refers to the claims being promoted about their ideas and how realistic they are. Especially in the context of novel technology, students might enter a hype cycle of high expectations at the early phase of technology development.

> *"Maybe kind of like persuasion for other people to accept your ideas if you're going to be a supplier to Equinor, you have to have some history of making them trust and ability to provide credibility to go forward with this project."*

4.2 Progression by imitation

Infants often mimic adults in their behaviours – which constructs deep into our cognition (Meltzoff and Decety, 2003). Students engage in conversations with actors knowledgeable about the field – they try to explain how the technologies work, their limitations, and their unique values. While students might not be fully aware of the technical specifications, they obtain a certain knowledge base that builds up their confidence. They also mimic actors they engage with, explaining the technology in such an attractive way to gather feedback from potential users and customers.

> *"I've come to the place where I build up such competence that I can at least ask the relevant and critical questions, I think. There's always a way to go until you're an expert on the laser."*

The imitation phase starts when students have talked with many customers, and they can see the potential problems, challenges, and needs from specific markets – they could use those patterns to further engage in a deep conversation and follow up as they are becoming knowledgeable about the field. Those patterns could be the language that these actors use, the kind of conversations or topics that might interest them, and the ability to understand and follow up on discussions. Gathering market feedback is used either (i) to validate the information students would like to test out – how feasible their ideas are or (ii) to obtain attraction on how likely their ideas are accepted.

"I think it's really important to talk to many people so that you know the pattern of how they're thinking. And then you can respond and ask questions back, and you can also predict which questions they will ask because you've talked to many, so you know how they're thinking."

In summary, we develop a conceptual framework of students' progression by imitation (Figure 3). Students make progress through the assimilation of new knowledge. To promote their ideas to potential customers and obtain new knowledge simultaneously, students pretend they are subject experts in the "imagined" applications of novel technologies to attract feedback and attentions from a wide range of stakeholders. In return, those feedbacks also support students in gaining new knowledge through an iterative, double-loop process of imitation.

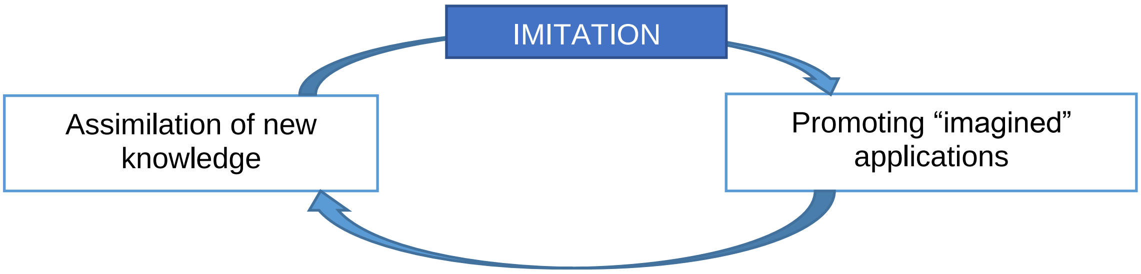

Figure 3: Progression by imitation

5 LIMITATIONS

One of the main limitations in this study is the timespan which the study was conducted during the NTNU-CERN Screening Week. Although this allowed us to have an in-depth analysis into how students make progression, we consider a longer longitudinal data collection in the future. It is more insightful for the understanding of how students interact with external actors to collect market insights. Another limitation is the process of visual mapping of students' ideation were done through researchers' interpretation instead of students themselves. We also propose a further study to investigate further on the imitation learning approach, especially the characteristics of this approach among students acting entrepreneurial. Another further study could also about how imitation influences the development of students' entrepreneurial ideas and future venture creation progress.

6 SUMMARY AND ACKNOWLEDGMENTS

In this paper, we explore how students generate market insights of novel technologies during a feasibility study. We identify two main steps which students link through imitation to progress their process – the assimilation of knowledge and promotion of imagined applications of the technology in focus. Our findings show that students use the initial insights to develop an idea of the application of the technology, gather feedback from the market by presenting the potential use of the technology as it is user-ready before the feedback is used to develop new insights about the potential use of the technology.

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