International Journal of Engineering Education Vol. 37, No. 6, pp. 1619–1629, 2021
Printed in Great Britain
0949-149X/91 $3.00+0.00

Development of a Collaborative Research Partnership Between Academia and Industry: A Case Study*

REUBEN F. BURCH V [1,2]**, LESLEY STRAWDERMAN,[1], GLENDA D. COLLINS[3],
JEAN MOHAMMADI-ARAGH[4], JIM MARTIN[5] and COURTNEY TAYLOR[6]
[1] Department of Industrial & Systems Engineering, Mississippi State University, Mississippi State, MS, USA.
[2] Human Factors & Athlete Engineering, Center for Advanced Vehicular Systems, Mississippi State University, Starkville, MS, USA.
[3] Southwest Workforce & Community Solutions, Southwest Tennessee Community College, Memphis, TN, USA.
[4] Department of Electrical & Computer Engineering, Mississippi State University, Mississippi State, MS, USA.
[5] Office of Research & Economic Development, Mississippi State University, Mississippi State, MS, USA.
[6] The Communiversity, East Mississippi Community College, Columbus, MS, USA.

This paper presents a case study of a mutually beneficial, 18-month long industry and academia partnership engagement process to assist others in establishing similar relationships. The partnership highlighted began with a single, unfunded graduate class project for a team of six students. Within 18-months, the partnership grew to 45 classroom projects, senior project designs (including capstone projects), graduate theses and dissertations, collaborative vendor/student research, and student competitions. During the three years following the 18-month case study, the industry-academia partnership continued to grow and resulted in multiple industry-funded research projects led by university faculty. Lessons learned from the partnership include 10 research-based collaboration strategies ranging from short term, low cast classroom projects to high cost, long term funded programs as well as nine industry brand awareness strategies for recruiting via future employee pipelines within the university. These lessons also include 11 project engagement steps that faculty can use to grow future funding opportunities. These engagement steps range from focusing on recruiting the right contact and champion, understanding the sense of urgency in project execution, to sustaining long partnered collaborations. Furthermore, the case-study established the need for a "bilingual" contact to support the communication between industry and academia partners.

Keywords: industry engagement; partnerships; classroom projects; student pipeline; industry funding; classroom involvement strategies

1. Introduction

The purpose of this paper is to recount a case study involving an industrial and academic partnership where Mississippi State University (MSU) faculty and engineers within a large corporation identified 19 different ways that industry could engage academia in both research and corporate brand awareness for recruiting. This case study recounts the entire process from the perspective of the industry partner as well as the lessons learned during the 18-month engagement period where multiple research techniques were utilized to better understand faculty consultations with industry funded projects. Many of the 19 different methods identified for engagement were tested during an 18-month process where MSU and a large corporate partner worked together to, first, understand each other's culture and, second, to create a research-driven roadmap for technology exploration and development. As a result, a partnership between MSU and a new industry partner was created as was a detailed list of 11 steps identifying how best to grow an industry partnership with academia. These 11 steps were then taught to other faculty members at MSU so that they, too, could begin to diversify their funding sources as universities everywhere prepare for leaner financial times. This paper provides evidence that growing a mutually beneficial partnership with a company from industry can be a lengthy process that, if handled successfully, can lead to long-term engagement, a hiring pipeline for graduating students, and funding opportunities.

1.1 Related Work

University-industry collaborations often take one of six organizational forms, ranging from informal personal relationships to formal agreements [1]. A wide range of factors can work to facilitate advantageous university-industry collaborations. These factors include choice of partners, contractual mechanisms, social issues, and project management [1–4].

There are significant barriers to establishing successful collaborations. One such barrier is the open-view of science and knowledge espoused by many universities, which is in direct conflict with the more guarded and confidential approach to knowl-

** Corresponding author: burch@ise.msstate.edu.

* Accepted 19 June 2021.

edge creation in many industries [5]. In addition, the debate over ownership of intellectual property can stop many collaborations before they begin [5].

Success in university-industry collaborations is multi-faceted and can be difficult to measure [6]. If successful, a university-industry collaboration can reap a variety of benefits including increased revenue, exposure of students to industry problems, joint publications, and enhancements to a university's reputation [1]. Furthermore, academic technology transfer has been shown to generate revenue, provide increased opportunities for funding and economic development, and benefit student experiences at the university [7].

Collaborations sought out by academic faculty or university researchers, referred to as academic engagement, has been shown to help further an academic's research agenda [8–11]. There has not been evidence to show any effect of academic engagement on faculty job satisfaction [12], which may be partially due to the undervaluing of commercialization and patent activities that are considered during the tenure process [13].

Case studies of successful university-industry collaborations (e.g., Barnes et al., 2002; Thune, 2011) have been used to demonstrate the prevalence of success factors and benefits that have been previously discussed in literature. In this paper, we present a case study involving an industrial and academic partnership between a research university (Mississippi State University) and a large organization (named LOGAN for the sake of this study).

1.2 Description of the Case

This case study is based upon the interactions between MSU and an organization that approached MSU with applied research needs and challenges. The primary contact and collaborator with MSU was a Chief Engineer from the organization's Research and Development (R&D) group who is familiar with both the academic setting as well as the industrial opportunities that would equate to proper challenges in which MSU could engage. While the names of the organization and the Chief Engineer described herein are fictitious, the content contained within this paper is based upon real events that took place between January, 2013 and July, 2014. In fact, the research relationship discussed is still active, healthy, and growing as of the writing of this paper.

1.3 Institution Overview

MSU is a land-grant and public research university that offers teaching, research, and local/national service. MSU has the largest enrollment in the state of Mississippi and has been classified as "Higher Research Activity" university by Carnegie Foundation. It is listed as the state's flagship university. The leading departmental collaborator, Industrial & Systems Engineering (ISE), aims to produce top caliber industrial and systems engineers through comprehensive, proactive, and evolving educational programs, to conduct and disseminate leading edge research and scholarship, and to provide service to engineers, companies, government agencies, and professional societies associated with industrial and systems engineering. Of all the industrial and manufacturing engineering departments in the nation, the National Science Foundation (NSF) has ranked the MSU-ISE department 21st in terms of research expenditures in fiscal year 2019.

The Center for Advanced Vehicular Systems (CAVS), founded in 2001, is a 55,000 ft^2 applied automotive research center with approximately $28 million in annual research funding. Supporting approximately 300 employees, CAVS has research groups focused on materials science, advanced electronic systems, computational fluid dynamics, and human factors & athlete engineering. CAVS is a member of MSU's High-performance Computing Collaboratory (HPC2), providing access to world-class supercomputing resources. Along with the ISE department, CAVS plays a significant role in organization engagement due to the interdisciplinary, collaborative nature of the research center. All disciplines of engineering, Kinesiology, Psychology, Sociology, Fashion Design, Communication, Health Sciences, Agriculture, Business and Marketing, and Athletics all work together seamlessly to focus on solving real-world problems.

1.4 Company Overview

Large Organization with Globally Affiliated Networks or LOGAN is a multi-billion-dollar, material-handling company that employs hundreds of thousands of workers at over 2,000 locations. LOGAN relies on a complex, widely distributed system for constant visibility into all product movement and status. In peak production times of the year, LOGAN can experience the movement of over a quarter-of-a-billion units within the distribution pipeline during only a few days' time. Therefore, because time is one of – if not the most – critical resource, tactical problem resolution or "daily firefighting" may often take precedence over strategic technology and research direction. Dr. Hank McCoy, a Chief Engineer and one of the primary technology strategists for LOGAN, was tasked with identifying and growing an academic partnership network to ensure that research technology resources would always remain free of the

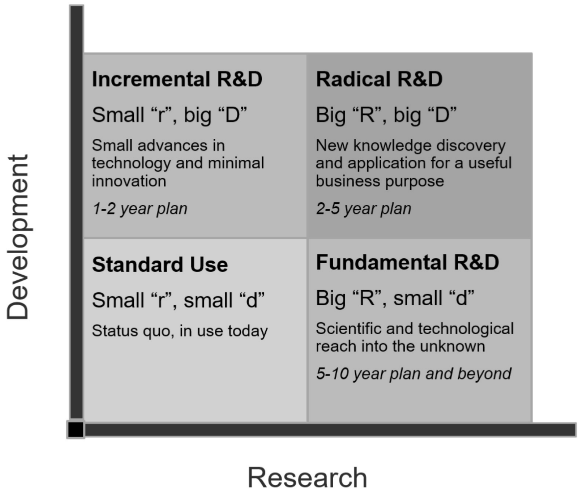

Fig. 1. Different levels (buckets) of R&D [15].

daily firefighting to think about the future without being bogged down in the issues created by the past.

1.5 Climate

For many reasons, government grant dollars are often considered by many academic measures to be the "greenest" and are therefore the most competitively sought. Faculty who are largely dependent on government grant funding alone may be at risk as funding sources vary when political change in leadership occurs. Likewise, military or country and state level department funding is another desirable source for research support given the often-large scope and duration of the contracts. But, similarly to government grant funding, a large military or similar-sized government departmental contract may be transitioned to another university or disappear entirely due to a political shift caused during an election year. With the changes to government budgets and the political landscape, diversification of funds is a concern, not just for MSU, but for many universities and tenure-track faculty across the United States.

Industry dollars are at times considered to be the least "green" in that winning a contract with a company is not always seen as being academically competitive. Also, keeping industry contracts and funding can be viewed as more difficult because real companies expect real, tangible results, not just some researched, theoretical solution that only works in a "vacuum". Another risk for industry money, as the 2008 recession and the more recent COVID-19 pandemic has shown, is that corporations are susceptible to unforeseen upheaval as well. However, as the financial landscape of academia continues to change (i.e., more faculty are competing for fewer grant dollars as state budget cuts increase), pursuing the least "green" color of money from industry may soon become a necessary contributor to research funding portfolios. Regardless of perception, executive staff in administration would state that all money spends the same and regardless of how competitive it was to obtain, it is needed to keep the lights on – an even more challenging thing to accomplish as all of 2020 has demonstrated.

2. Presentation

2.1 Academic "Fit" in Industry R&D

There was general agreement at LOGAN that academic partnerships were needed to quickly expand technology awareness and improve R&D direction but there were still questions from executive leadership regarding where exactly universities would contribute to the overall discovery process. McCoy put together a simplistic R&D roadmap based on a combination of commonly accepted R&D practices [15] and Boff's generations of human factors and ergonomics [16]. He first explained to executive leadership that there are three levels or "buckets" of R&D where most technological advancement for the company can fit: incremental, radical, and fundamental [15] (Fig. 1).

Defining what R&D is in simple terms allowed McCoy to paint a bigger picture to executive leadership for where exactly academia would fit within a business plan where multiple vendor partnerships already existed. LOGAN largely works with vendors to pursue next generations of technologies for implementation in their facilities. The desire was not to supplant vendors or risk potential damage to those relationships, but to augment the dynamic in a way that all parties would find mutually beneficial. Fig. 2 is the "sales pitch" and concept that McCoy presented to leadership to quickly explain academic fit and purpose in the company's overall R&D strategy. The "Innovation Triforce" – to borrow a term from a popular series of video games [17] – shown in Fig. 2 was determined to be the ultimate end goal for LOGAN as McCoy often stated during his pitch to executive leadership: "Industry needs the tool, vendors build the tool, and universities revolutionize the tool."

2.2 An Approach to Selecting Academic Partners

Before McCoy identified and approached potential university collaborators, he first had to translate the research needs of LOGAN into partnership requirements or university "ingredients" that would define what he called the mutually beneficial partnership "secret sauce." McCoy knew he would need to justify his academic partner selections to executive leadership and so he created a short list of

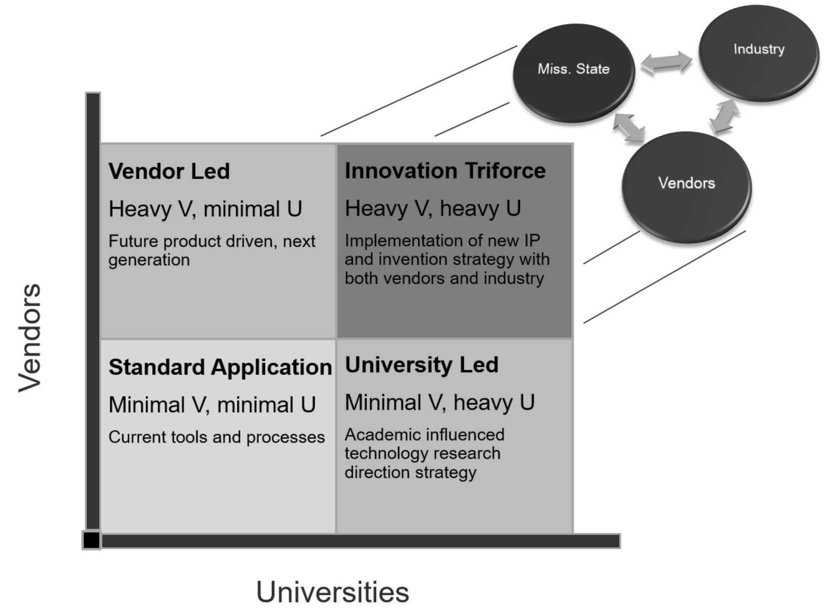

Fig. 2. Vendor-university engagement strategy and the "Innovative Triforce."

ingredients that were used to first, find a university and later, to justify their collaboration potential. Table 1 shows secret sauce considerations that McCoy identified as well as previous lessons used to validate the ingredients. Note that these ingredients were specific to the LOGAN work culture and are not expected to be the same for all organizations.

Table 1. Academic engagement ingredients for LOGAN and previously encountered partnership challenges justifying each ingredient

University Partnership Ingredients	(Previous Experience) Lessons Learned
Strong engineering or other relevant programs with well represented disciplines that meet business needs.	LOGAN is primarily an engineering-based company with a research focus on future technology.
Faculty willing to incorporate real-world problems into the classroom and graduate research.	LOGAN would prefer to hire the students who work on their research and so integrating their analyses into the curriculum would make the partnership more attractive.
Larger institutions primarily focused on applied sciences and agriculture.	Theoretical research is necessary in R&D, but discoveries must be applied within reasonable timeframes to justify the expense (i.e., quick win mentality). University partners need to understand how to execute solutions. Land-grant universities have long histories of providing application-based services to their state and locally based organizations.
Government and/or military research ties and funding.	During the timeframe of this case study, Uber hired away many top researchers from Carnegie Mellon's robotics lab, NREC (National Robotics Engineering Center) [18], [19]. This takeover made LOGAN executive leadership wary of working with any research center for fear of losing proprietary information. This concern was mitigated by focusing on universities with large military ties and funding because, unlike a corporate entity, the government is less likely to hire away entire teams of researchers.
Multidisciplinary teams comprised of faculty across the entire campus from multiple colleges.	LOGAN executes using project teams comprised of people across the company who have different skills and communicate through designated points of contact. University partners will be expected to do the same as faculty and researchers will need to cooperate and communicate effectively.
Flexibility with intellectual property (IP) ownership, contract negotiations, and publication opportunities.	IP negotiations between large organizations can take months, possibly years, delaying any research progress. LOGAN was willing to negotiate that faculty could publish research if the university was willing to assign IP findings to LOGAN. This was one of the most significant requirements.
Advisory Council, Faculty Consultant, and Student Advisor opportunities at the discipline and college levels.	These opportunities were a way to stay engaged at multiple levels within the academic partnership thereby providing ways to stay in communication even if funded research wasn't currently active.
Others include: location, previously established internal connections, existing academic corporate partnerships, and rankings.	Most of these are self-explanatory, however, rankings proved to be the least important as high rankings do not address a university's ability to execute on real-world problems nor do high rankings indicate faculty who are capable of or interested in doing applied research.

Multiple universities were approached about becoming academic partners for key areas of LOGAN's technology research interests. All the ingredients (Table 1) were used during the evaluation, but McCoy found that the universities with the highest probability of entering negotiations met the following criteria: (1) had an existing internal connection between the university and the organization, (2) the university was willing to negotiate assignment of intellectual property, and (3) the university had interdisciplinary teams experienced at collaborating and executing deliverables effectively.

Ultimately, MSU was one of the universities identified for consideration as a potential academic partner because LOGAN hires many MSU engineering graduates. Also, MSU placed preference on establishing the industry partnership and publication opportunities while being willing to provide patent assignment of all future invention outcomes to LOGAN. Finally, the research centers at MSU, such as CAVS, have a culture of encouraging cross-university, interdisciplinary project teams through years of military-focused project deliverables.

3. Discussion

During the process of identifying the right academic partners (i.e., *who* LOGAN partnered with), McCoy knew that equally critical aspects were *how* they partnered which is the primary takeaway for this case study.

3.1 Methods Industry Can Use to Engage Academia for Research

Through an informal yet extensive interview process with multiple universities and departments within those universities, McCoy was able to identify 10 different ways that an industry partner such as LOGAN could partner with academia for research purposes. Fig. 3 is an actual snapshot from a presentation given to executive leadership at LOGAN quickly explaining each research opportunity from the smallest financial commitment (Classroom projects and labs) to the largest (Funded research programs). Fig. 4 is a very high-level, representation of resource allocation for each of the research engagement opportunities so that leadership, immediately, could quickly grasp level of commitment versus realistic output. A score of 1 denotes low resource commitment and increases to high commitment at a score of 4.

3.2 Methods Industry Can Use to Engage Academia for Brand Awareness

McCoy recognized that, in addition to the research itself, there was high value in installing a pipeline for quality future hires. Through his informal interview process with key universities and departments, McCoy learned that the most talented students generally had a good idea of where they intended to work after graduation as early as their sophomore year. Companies that engaged students early, often, and provided internship and co-op opportunities

Fig. 3. Ten different industry research engagement opportunities with academia.

	MONEY	PEOPLE	TIME	AWARENESS	SCOPE
Paid Research	4	2	3	2	4
Student labs and visualization center sponsorship	4	1	1	4	3
Grad student sponsorship	3	1	2	1	3
Continued education project sponsorship	2	1	2	2	3
Student competitions	2	3	3	3	3
Part-time teaching, advisement, and mentorship	1	4	4	4	3
Collaborative vendor/student research	1	2	1	2	2
Graduate research (Masters and Doctorate)	1	2	2	1	2
Senior project design	1	2	2	4	3
Classroom projects, labs, and Capstone	1	1	1	3	1

Fig. 4. Academic research method engagement resource commitment visuals. Note that Awareness in this figure refers to classroom awareness on the part of the students regarding the organization sponsoring the work.

tended to get top tier student commitment well before they entered their senior year. To get the attention of these younger students for internship and co-op opportunities, organizations successful in recruiting kept a campus presence and developed a strong brand awareness. Knowing that a long-term, mutually beneficial partnership between industry and universities would require a consistent level of student recruitment for both the on-campus research as well as future workforce hires, McCoy identified nine different methods for developing brand awareness amongst the students. He used the structure of the Brand Awareness Pyramid [20] to provide a greater level of context for the level of commitment required. Fig. 5 provides another snapshot from a presentation given to LOGAN executive leadership. This student recruitment pipeline was necessary, not only for future hiring at LOGAN, but for recruitment of students to the research teams of planned and potential funded projects. Creating a pipeline of young students who work on funded R&D-based projects and then go on to apply for permanent jobs

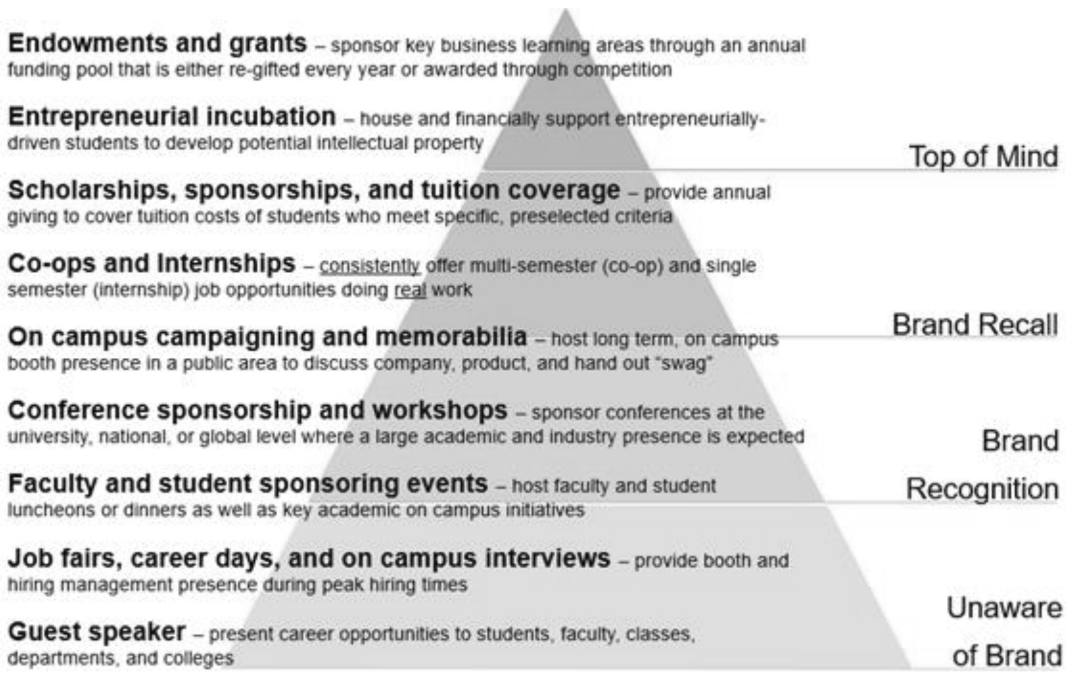

Fig. 5. Nine different brand awareness opportunities with academia.

creates opportunities for hiring managers to have confidence that their future staff are already well versed in LOGAN work culture and knowledgeable of the job expectations. Working on a multidisciplinary research team as a student in R&D projects also creates a critical background in soft and entrepreneurial skills, a skillset often overlooked but very important for personal and career growth for engineers [21, 22]

3.3 Steps to a Partnership

MSU and LOGAN were able to successfully grow a mutually beneficial partnership that has persisted after the end of the "dating" period. But for LOGAN to have an academic network and for MSU to further increase industry-specific funding, both need to increase their partnerships beyond one another. With assistance from McCoy, MSU was able to identify all the key steps that acted as phase gates through different levels of the LOGAN-MSU partnership allowing forward momentum toward something that was both permanent and mutually beneficial. Faculty and ORED at MSU were asked to summarize the key takeaway points from this partnership and package them into presentation materials for other faculty, other schools in the state, and other industries in the region on how to better partner such that all involved in the collaborative process can win through either R&D findings or research funding. Many of these points had been captured through the success highlights in the monthly, quarterly, and annual reporting due from MSU to LOGAN, and from LOGAN engineers to their leadership. To fill in the gaps and to add context around the success points, interviews were then conducted by the lead faculty of the LOGAN projects to create actionable steps for later partnership creation duplication. Because these steps were identified after the 18-month dating period, the researchers involved in this case study performed informal interviews with research project participants from both MSU and LOGAN to identify where the process was successful. These interviews used question themes to focus on areas such as: (1) What made the partnership succeed? (2) What early-stage communications and decisions enabled the partnership discussions to develop further? (3) Which people and which skillsets were necessary (both academic and industry) for furthering the partnership discussions? (4) What level of involvement was needed to stay engaged? Who needed to be involved early, often, and sold on the process? (5) What communication elements were used to convince upper management of the worth of the partnership? (6) What characteristics needed to be demonstrated during the dating period to prove value? And (7) what could have been done better? While unsolicited, additional insight was provided on the part of both organizations regarding past attempts to grow partnerships with other entities and the lessons learned on why they were unsuccessful. Table 2 outlines the 11 steps (each complete with those previous mentioned, additional insights) that academia should take to grow an organic, mutually beneficial partnership. These steps have since been presented by the Office of Research and Economic Development (ORED) within MSU to faculty looking to begin or increase their relationship with industries that could benefit from their research. McCoy has also presented these steps to other potential academic partners for LOGAN.

3.4 Partnership Results

The official MSU and LOGAN dating period began in January 2013 with a single graduate class project for a team of six students. The research was unfunded, and the topic was of interest to McCoy and the R&D team but was not high enough of a priority to have any engineering resources from LOGAN allocated to it. The project was initiated by McCoy traveling to MSU to present the research idea to the graduate class. One project team of six students agreed to the project and so McCoy arranged for the team's travel to the LOGAN facility where they conducted interviews and surveys (upon LOGAN legal team's approval of all materials and staff interactions prior to the visit). Throughout the semester, McCoy was in contact with the student team at least twice a month. At the project's conclusion in April 2013, middle management from LOGAN traveled to MSU to be present for the final report and recommendations. The project was not complicated nor were the solutions presented by the students much different than what was suspected by the R&D team; however, the completed research was enough to justify how students could be used to supplement lower priority research interests at LOGAN. This initial research effort would go on to spawn continuations of the research in future classes during later semesters. A student from this first graduate class was hired into the R&D group at LOGAN to work with McCoy and the recommendations from that initial student research project were implemented in a production facility in February 2016. This project was the success that MSU needed to get the attention of executive leadership at LOGAN and for McCoy to justify the value of academic partnerships.

As of May 2016, 45 classroom projects, senior project designs (including capstone projects), graduate theses and dissertations, collaborative vendor/student research, and student competitions have been completed between MSU and LOGAN and continue to grow today. During the most produc-

Table 2. Eleven steps identified for how academia can grow a mutually beneficial partnership with industry

#	Step Goal	Key Insights from Lessons Learned
1	Establish a contact within the industry/organization	(a) Preferably someone in management who has a budget or someone who has influence over the budget. (b) Contact will need to serve in an "evangelistic" role and "sell" the need for the relationship.
2	Learn to speak the industry language	(a) Get an understanding for the problems that your future partner cares most about. (b) Begin to think about applied solutions rather than strictly theoretical (industry might not care about fun and cool). (c) Understand that industry has a much stronger sense of urgency for completing usable solutions.
3	Identify small, quick win opportunities of interest to the industry partner and propose free assistance through the research engagement strategies	(a) Make sure to pick small projects that have a high probability of success. (b) Emphasize projects that might not involve much or any organizational proprietary information. (c) Consider class projects, senior project design, thesis and dissertation topics, letters of support for grants, etc.
4	With one or multiple industry driven, small research ideas in mind/ progress, begin discussions of getting a Non-Disclosure Agreement (NDA) signed to mitigate industry concerns about sharing proprietary information.	(a) Explain the nuances of what the university will expect in the agreement (learn some legalese; for instance, the laws of the home state of the university will dictate agreement terms and universities will not be indemnified). (b) Proactively approach the potential intellectual property discussion and who gets rights to what even before Collaborative Research Agreement (CRA) officially begins between legal teams.
5	Keep the industry partner involved at some level throughout the course of the project(s).	(a) Invite the partner to present the problem in person, to have multiple touch points throughout the project, and to actively participate in the review of the final delivery. (b) Use this as an opportunity to introduce the partner to more faculty and resources at the university instead of keeping them focused in a single, isolated academic area. (c) Use this as an opportunity to network with more people from the industry side and to offer higher ranking officers' opportunities to judge, review, or even guest speak at university events (typically for no cost).
6	Ensure that the results of the first project(s) are very successful and (typically) still very free.	(a) At the end of the first collaboration, be able to use the project as an example for why the partner should be doing even more collaboration with the university. (b) Advertise that students on the project are available for hire and, because of the project, now already understand the work culture of the industry partner. (c) Suggest collaborating on journal papers, conference presentations, and even press releases.
7	Repeat the process of finding small problems and solving them for little to no budget over the next semester or two (if needed).	(a) A true partnership takes time to grow and establish, create the perception that the university has been a long-term partner and is able to help solve problems the organization would have otherwise not had time or resources to solve on their own. (b) Make the case that success has been achieved for little to no financial commitment so that when funded project proposals are provided, there is already a track record of success.
8	Provide short funding proposal descriptions based on industry's larger needs.	(a) No matter how small, get the industry partner to financially invest either in funded projects or in students so that a partnership is official established on paper. (b) Know and incorporate the strengths of your university in order to better sell why the university is the right partner.
9	Use the first funding opportunity to flesh out all legal contract negotiations and discussions.	(a) Potential intellectual property will be the biggest part of the discussion; use this to leverage the right to publish based on the research being conducted. (b) Contract negotiations for new partners are the single most painful part of working with medium to large companies; by finalizing negotiations early in the partnership, other areas of the company are more likely to invest simply because the legal components have so much overhead in the past.
10	Prove that the university understands the expectations of the industry culture.	(a) Through your funded project deliverables, prove that you understand deliverable expectations of the industry culture in terms of report formats, presentation style, appropriate communication level, and applied solutions. (b) Unlike grants, companies need to see value for every dollar spent. If a company spends \$50K on a project to collect data and provide results which include a literature review but the end deliverable is a 6-page PowerPoint slide and a 10-page report, the industry partner might be upset because, despite the work that went into collecting the data, 6 slides and 10 pages doesn't feel like something worth \$50K.
11	Continue the free project opportunities to be further engrained into the industry partner's culture.	(a) The key to ensuring that the collaboration continues lies in ensuring the university stays in view of the industry executives. (b) To further spread throughout the industry partner's work and research culture, expand research collaborations to include key vendors and vendor technology solutions. (c) Carefully include other universities that already have a preexisting relationship with the organization or with the organization's executive leadership; emotional attachments by employees and executives to their alma maters can hinder partnership progress.

tive semester (from an unfunded perspective), over two-dozen student project teams, including nearly 150 students, were working on LOGAN-based research collaborations in the classroom. Many of these students have been hired for summer internships which have led to fulltime job offerings from LOGAN.

Three semesters or approximately 18 months' worth of unfunded classroom projects were needed to successfully earn the trust of executive leadership at LOGAN so that funded research opportunities could begin. In July 2014, a research proposal with a financial expenditure greater than \$100K was proposed by MSU to LOGAN R&D and executive leadership. Due to the preexisting research history that had been established in the classroom, LOGAN accepted the proposal thus ending the dating period and making the partnership officially known throughout the organization. Before the conclusion of this first funded project, LOGAN requested proposals from MSU regarding an effort to create a completely new research direction. MSU responded with 29 funded research proposals. Eight proposals were accepted for a phase one approach with many more earmarked for later research phases. A long-term research collaboration was officially executed in August 2015, over two-and-a-half years since the beginning of the first classroom project. A second phase of research was accepted after the first completed and funded efforts continued through 2018 marking a success that spanned over three years.

One of the first and most important lessons learned during this process is that someone, either on the industry or academic sides of the partnership, should be aware of how both entities work, conduct their business, and understand end-goal expectations for collaborated projects. Without a "bilingual" contact to bridge the communication gap, a partnership between academia and industry would have been difficult to grow organically within the span of 18 months.

4. Conclusions

Based on a case study of a mutually beneficial industry-academia partnership, this paper presents 10 techniques that industry can use to engage academia for research, 9 methods that industry can use to engage academia in brand awareness to improve recruitment and hiring, and 11 steps faculty can use to cultivate mutually beneficial partnerships to establish new funding opportunities. The strategies presented herein were successfully used to establish and grow a partnership from a single, unfunded classroom project to a relationship supporting multiple classroom projects, student theses, and funded research projects of over \$2.5 million. This paper highlights the time investment required to grow a successful partnership; it would be challenging to establish a brand-new, strong partnership like the one described in this paper in less time than 18-months.

While this paper focused on a partnership with a large multi-billion-dollar company with its own research and development unit, many of the strategies presented are relevant for establishing industry-academia partnerships with smaller firms. For example, small civil engineering firms may not have funds available to sponsor research projects, but half of the 10 techniques for engaging academia shown in Fig. 4 were evaluated as low monetary cost. The evaluation results could be used by smaller firms to identify strategies that are consistent with their individual industry needs.

Finally, one major takeaway from this endeavor was that strong partnerships require a single person who understands both industry and academia goals. That person serves to interpret and situate conversations between the two different entities. For universities seeking to establish industry partnerships, investing in "bilingual" contacts should be a priority. Universities could include industry experience as hiring criteria for some faculty positions. Universities could also create industry liaison positions within their offices of research or centers for teaching and learning. Establishing industry and academia partnerships can benefit both entities, especially when the partnership includes someone who understands how different needs, timelines, and approaches within industry and academia can align.

References

1. S. Ankrah and O. AL-Tabbaa, Universities-industry collaboration: A systematic review, *Scand. J. Manag.*, **31**(3), pp. 387–408, Sep. 2015.
2. R. Fontana, A. Geuna and M. Matt, Factors affecting university-industry R and D projects: The importance of searching, screening and signalling, *Res. Policy*, **35**(2), pp. 309–323, Mar. 2006.
3. R. Rybnicek and R. Königsgruber, What makes industry–university collaboration succeed? A systematic review of the literature, *J. Bus. Econ.*, **89**(2), pp. 221–250, Mar. 2019.
4. T. Thune, Success Factors in Higher Education-Industry Collaboration: A case study Of collaboration in the engineering field, *Tert. Educ. Manag.*, **17**(1), pp. 31–50, Mar. 2011.

5. J. Bruneel, P. D'Este and A. Salter, Investigating the factors that diminish the barriers to university-industry collaboration, *Res. Policy*, **39**(7), pp. 858–868, Sep. 2010.
6. M. Perkmann, A. Neely and K. Walsh, How should firms evaluate success in university-industry alliances? A performance measurement system, *R&D Manag.*, **41**(2), pp. 202–216, Mar. 2011.
7. V. L. McDevitt, J. Mendez-Hinds, D. Winwood, V. Nijhawan, T. Sherer, J. F. Ritter and P. R. Sanberg, More than money: The exponential impact of academic technology transfer, *Technol. Innov.*, **16**(1), pp. 75–84, Jun. 2014.
8. Y. S. Lee, The sustainability of university-industry research collaboration: An empirical assessment, *Journal of Technology Transfer*, **25**(2). Kluwer Academic Publishers, pp. 111–133, 2000.
9. M. W. Lin and B. Bozeman, Researchers' industry experience and productivity in university-industry research centers: A 'scientific and technical human capital' explanation, *J. Technol. Transf.*, **31**(2), pp. 269–290, Mar. 2006.
10. A. N. Link, D. S. Siegel and B. Bozeman, An empirical analysis of the propensity of academics to engage in informal university technology transfer, in *Universities and the Entrepreneurial Ecosystem*, vol. 16, no. 4, Edward Elgar Publishing Ltd., pp. 97–111, 2017.
11. M. Perkmann, V. Tartari, M. McKelvey, E. Autio, A. Broström, P. D'este, R. Fini, A. Geuna, R. Grimaldi, A. Hughes and S. Krabel, Academic engagement and commercialisation: A review of the literature on university-industry relations, *Res. Policy*, **42**(2), pp. 423–442, Mar. 2013..
12. B. Bozeman and M. Gaughan, Job Satisfaction among University Faculty: Individual, Work, and Institutional Determinants, *J. Higher Educ.*, **82**(2), pp. 154–186, Mar. 2011.
13. P. R. Sanberg, M. Gharib, P. T. Harker, E. W. Kaler, R. B. Marchase, T. D. Sands, N. Arshadi and S. Sarkar, Changing the academic culture: Valuing patents and commercialization toward tenure and career advancement, *Proceedings of the National Academy of Sciences of the United States of America*, **111**(18). National Academy of Sciences, pp. 6542–6547, May-2014.
14. T. Barnes, I. Pashby and A. Gibbons, Effective university – Industry interaction: A multi-case evaluation of collaborative R&D projects, *Eur. Manag. J.*, **20**(3), pp. 272–285, Jun. 2002.
15. P. Roussel, K. Saad and T. Erickson, *Third generation R&D management*, Boston: Harvard Business School Press, 1991.
16. K. R. Boff, Revolutions and shifting paradigms in human factors & ergonomics, *Appl. Ergon.*, **37**(4) SPEC. ISS., pp. 391–399, 2006.
17. J. Walls, *The legend of Zelda and theology*, Gray Matter Books, 2011.
18. L. England, Uber Hires University Researchers to Work on Self-Driving Cars, *Inc.*, 2015. [Online]. Available: https://www.inc.com/business-insider/uber-poached-researchers-from-carnegie-mellon.html.
19. J. Lowensohn, Uber gutted Carnegie Mellon's top robotics lab to build self-driving cars, *The Verge*, 2015. [Online]. Available: https://www.theverge.com/transportation/2015/5/19/8622831/uber-self-driving-cars-carnegie-mellon-poached.
20. K. L. Keller, *Strategic brand management: Building, measuring, and managing brand equity*, Pearson Education India, 2011.
21. R. Jafari-Marandi, B. K. Smith, R. F. Burch and S. C. Vick, Engineering soft skills vs. engineering entrepreneurial skills, *Int. J. Eng. Educ.*, **35**(4), pp. 988–998, 2019.
22. T. J. Siller and J. Durnin, University-industry partnership to develop engineering students' professional skills, *Int. J. Eng. Educ.*, **29**(5), pp. 1166–1171, 2013.

Reuben Burch, PhD, is Associate Director of Human Factors & Athlete Engineering at the Center for Advanced Vehicular Systems, Assistant Professor of Industrial & Systems Engineering, Faculty Research Fellow at National Strategic Planning & Analysis Research Center, and founder of Athlete Engineering at Mississippi State University. He has more than 14 years of industrial experience. His research interests center around human factors, cognitive engineering, macroergonomics, and human-technology interactions with the sports, industrial, tactical, and at-risk populations.

Lesley Strawderman, PhD, is Professor and International Paper Endowed Chair in the Department of Industrial and Systems Engineering at Mississippi State University. Her research expertise is in human factors engineering and engineering education. She has specific interests in technology acceptance modeling, transportation safety, and engineering student efficacy. Dr. Strawderman is a registered Professional Engineer and is an active volunteer in the Society of Women Engineers, Institute of Industrial and Systems Engineers, and ABET.

Glenda D. Collins, PhD, recently served as Director of Workforce Programs and Partnerships at Southwest Tennessee Community College. Dr. Collins revitalized SouthwestWORKS, a training program recognized in the Mid-South region that offers a holistic three tier workforce development solution of essential (professional) skills, technical training, and a credential. She is dedicated to connecting individuals to career pathways via workforce training, university industry partnerships, student recruitment, and research.

M. Jean Mohammadi-Aragh, PhD, is Chief Diversity Officer and Assistant Professor in the Department of Electrical and Computer Engineering at Mississippi State University. Her research expertise is in engineering education. She has specific interests in programming skill development, computational thinking, and pedagogical uses of digital systems. Dr. Mohammadi-Aragh also investigates fundamental questions related to engineering communities, identity, and messaging, which are all critical elements for improving diversity within the field.

Jim Martin is the Associate Vice President for Corporate Engagement and Economic Development at Mississippi State University. Jim graduated from Mississippi State University in 1985 with a bachelor's degree in accounting. He also holds master's degrees in Management and Strategic Studies. After graduation, Jim served 32 years in the Air Force. In his last assignment, Major General Martin was the Air Force Budget Director, responsible for annual budgets totaling over $132 billion.

Courtney Taylor, PhD currently serves as Vice President of Workforce and Economic Development at East Mississippi Community College in Columbus, Mississippi. Dr. Taylor is responsible for workforce development activities, including The Communiversity, which is a 145,000 square foot advanced manufacturing training facility dedicated to inspiring, informing, and training the local workforce. The Communiversity houses advanced manufacturing and workforce training programs guided by local industry partners and is anchored by collaborative community partnerships.