Work-based learning: integrating academia, industry, and community

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Abstract

This research paper presents a comprehensive analysis of a work-based learning model based on the principles of PBL and its positive synergistic effect on students, industries, and communities. The model is active in multiple communities in the United States. This paper will focus on the synergistic effect in a rural region of the upper Midwest. The model integrates academic instruction with hands-on industry experience, cultivating a collaborative environment that prepares future engineers to address complex challenges.

The paper explores how the model's partnerships with local and regional industries provide students with immersive, real-world learning experiences that enhance technical competencies, boost employability, and foster a mindset of lifelong learning. The paper also explores how industry partnerships drive innovation and generate social and economic benefits for the region, contributing to its resilience and growth. By supplying a skilled workforce to local industries, the model plays a critical role in community development, addressing both immediate industry needs and long-term sustainability. Additionally, the paper underscores the importance of community engagement, demonstrating how an integrated approach between academia, industry, and local stakeholders can yield significant advancements in engineering education and societal progress.

The findings offer insights into the transformative potential of work-based learning models linking education, industry, and community engagement, advancing engineering education and broader societal development.

Keywords: work-based learning, industry partnerships, community engagement

1 Introduction and background

Engineering Education has seen periods of evolution, innovation, and growth to meet the changing needs of society. A significant step was in 1989 when professional organizations from Australia, Canada, Ireland, New Zealand, the United Kingdom, and the United States formed what became the Washington Accord (Beanland & Hadgraft, 2013). It sought to establish standards for professional competencies and a competency focus for engineering students graduating from an accredited institution. Within the U.S. engineering education community, ABET, the non-governmental accrediting body for engineering education in the U.S., introduced in 1996 a new set of engineering accreditation criteria, the ABET Engineering Criteria 2000. Throughout the past quarter century, conferences, research, and scholarly activities have continued to focus on the need for engineering education to evolve, innovate, and grow at a rate that matches the accelerated rate of change being experienced in society (Sorby & Fortenberry, 2021).

One model recognized (Graham, 2018) for its exploration and innovation is the Iron Range Engineering (IRE) program. Developed as a project-based learning (PBL) model to address the growing gap between the skills and knowledge needed for professional practice and what was being acquired by graduation (Ulseth et al., 2011), it was adapted (Bates et al., 2024) from the Aalborg University PBL model (Kolmos et al., 2007). Student learning is focused on the development of the "whole student" through professional, design, and technical learning at workplace-ready levels by graduation. This contrasts with the traditional curriculum's primary focus on the technical learning domain (Sheppard, 2009).

The *design domain* focuses on developing the skills necessary to scope, manage, evaluate, and present engineering projects, emphasizing program graduates' ability to directly contribute to project management while fostering an innovative and creative mindset. The *professional domain* focuses on the professional skills of communication, the ability to work on teams, and understanding the professional and ethical responsibilities of an engineer being developed to a workplace-ready level by the time they graduate. The *technical domain* focuses both on developing the traditional technical knowledge that engineers need for practicing in their discipline and, equally important, the ability to identify and develop the technical knowledge when they need it.

The initial PBL curriculum began in 2009 with a focus on industry-sponsored academic projects that were completed within the physical and operational structures of the institution, with interaction with professionals at the sponsoring company. By 2016, it was becoming clear that further development of the IRE model was needed (Ulseth & Johnson, 2023). It came both from the learning experiences of some students utilizing co-op or work-based learning experiences instead of the on-campus industry-sponsored projects and from the desire to 1) empower students to use employment to help fund their education while gaining recognizable experience, 2) utilize the emerging technologies for online learning, and 3) increase access to the engineering profession by designing it specifically for community college students bringing a wider student demographic diversity than the university counterparts to the profession of engineering. (Johnson et al., 2018). In 2019, the curriculum was reinvented by merging the original IRE model with the co-op placement model from the engineering program at Charles Sturt University (CSU) (Lindsay & Morgan, 2021).

In the new IRE Bell model, the lower-division (the first two years of a bachelor's degree) courses are completed at a community college anywhere in the U.S. This is followed by a one-semester, on-ground, intensive session called the Bell Academy, where participants began taking their upper-division technical courses, acquire the professional and design skills needed for their co-op experience, and develop the job-search skills to acquire the co-ops. After the Bell Academy, students spend 24 months doing full-time co-op work paired with 10-12 hours per week of continued coursework in the domains of technical, professional, and design learning. Integral parts of the learning experience are the students' learning coach (mentor), reflection, and being evaluated on their learning (Bates et al., 2020; Ulseth et al., 2021).

The program features of the IRE Bell Model align with the four modern learning principles behind PBL, as identified by Maastricht University (Dolmans et al., 2005): 1) Constructive learning, 2) Learning in a relevant context, 3) Collaborative learning, and 4) Self-directed learning.

<u>Constructive learning</u>

Learning in the IRE model is an active process where students gain knowledge from their experiences and interactions within the work environment. On projects, students are encouraged to think about what they know already, learn new information, and then learn to integrate new information with their prior knowledge to complete the project at hand. Facilitators, engineers with experience who return to mentor students in the program (Johnson et al., 2018), serve as learning coaches and work one-on-one with students through weekly conversations. These conversations focus on the student's short-term and long-term goals regarding the development of their design, professional, and technical domains. These relationships start in the academy and continue through the two years of co-op work placements. This process helps students to truly understand the subject matter and form well-founded opinions about what is and what isn't valuable and how to acquire new knowledge; all of this contrasts with the traditional engineering education model of just learning things by rote. Student retention of knowledge is higher.

<u>Learning in a relevant context</u>

Student projects are the current projects that a company is actively working on with all of the unique challenges, making solutions work in a current and rapidly evolving society and in an environment not based on academic peer or faculty approval but on the approval of the market and society the project solution serves which have direct meaning as an engineer for today's society. The project timing is based on the company's timeline vs an academic timeline; therefore, students will find themselves joining project teams to finish a project, start a project, and occasionally for the entirety of the project. The authenticity of these industry projects and the timing piques students' motivation as they see the actual value and impact of their work as they are directly involved with practicing engineers and multi-functional teams.

In addition to the "on the job" development during the day of their professional, design, and technical skills, students additionally spend approximately 15 hours documenting their design/professional learning and taking evening technical courses while visiting and evaluating their learning with their mentor (i.e., learning coach) on a regular basis. Being confronted with the complexities and intricacies of work-based projects, IRE Bell graduates have spent two years tackling a wide variety of societal and technically relevant topics and developing their ability to make the all-important knowledge transfer from theory to practice.

<u>Collaborative learning</u>

The entire IRE Bell learning model encourages students to learn from and discuss their learning with peers, mentors, and industry colleagues. This begins during the academy, where the proximity of students to one another builds a strong sense of community both in the social aspect and also in their learning. At the end of each academy, students who are one or two years into their co-op placement return for exams and professional development weeks, during which students develop peer relationships with those who are a few steps ahead and build a better understanding of what their learning progression will look like. By exchanging ideas and providing feedback with their peers, mentors, and work colleagues, IRE Bell graduates understand the professional, design, and technical learning domains better. They realize that the learning process is not an individual one; it is developed in a social construct where the responsibility is for both the group and the individual to develop their domain knowledge.

<u>Self-directed education</u>

The learning process of IRE Bell is something students manage themselves by planning, monitoring, reflecting, and evaluating (Ulseth, 2016). The faculty and mentors are there to assist, but from the start of the program application process, through the Bell Academy, while finding co-op placements, and throughout the 24 months of learning in industry, the students remain the driving force of their learning.

Student learning initially takes place in the academy through a core set of one-credit modules that focus on two to six fundamental principles for a given topic versus attempting to teach "everything". These modules build on the information from the student prerequisite courses from their lower-division studies. Students are held accountable for carrying the fundamental principles to future courses, academy projects, and during their industry placements. Students then select future courses during their industry placements that directly support what is needed in their industry applications and are relevant to their engineering discipline.

As students progress through the program, they continuously build on the ability to direct their learning in a motivating and effective way that reflects the Sheppard (2009) helical learning cycle (Sheppard, 2009). The experience builds the lifelong learning ability and desire of students.

<u>Importance of community engagement</u>

Given the social construct of PBL, engagement in a peer community is necessary to build and cultivate strong social connections between student-to-student and faculty-to-students (Christensen et al., 2023).

These connections are fundamental to building a culture that builds relationships and fosters the student and professional development necessary in both the program, supporting retention, persistence, and identity building (Bates et al., 2024) in their future professional practices. Community is developed through three activities during the Bell Academy: 1) students live in a dormitory community environment, building the overall community for that cohort; 2) students have project rooms for their projects to build community within their project team; and 3) through student-life activities to further build a student's connections with both faculty and students. The relationships built continue to support students as they individually go into industry through continued, albeit remote, shared learning experiences and networking activities to both support their learning and project work.

Student participants identify this culture (Johnson & Ulseth, 2017) as strengthening the project and learning activity experiences in their development, especially in their professional competency development. The culture reinforces the practice of students conducting themselves in a professional manner on a continuous ongoing basis and not on a "just when they have to" basis.

2 Fostering a life-long mindset

2.1 Fostering a life-long learning mindset -methods

Student engineers use reflection as an essential part of their overall development. Called "learning journals," the students are given approximately 25 prompts during each of their five learning semesters. They respond to these prompts with ½ to 1 page of written reflective analysis. Some prompts are given once during the 2.5 years, while others are repeated from 1 to 4 times throughout the student experience. Data to analyze the lifelong learning mindset came from a 1-time prompt in the fifth semester called "Lifelong Learning" and from a prompt given both in their first semester (Bell Academy) and again in the fifth and final semester before graduation called the "Metacognition Memo."

Research Question: In what ways do the graduating students of the work-based learning program demonstrate the development of lifelong learning skills?

Data was gathered from the one-time Lifelong Learning journal entry and then paired before and after Metacognition Memos. The 10 graduates highlighted in this study were selected at random, and all data was accessed and analyzed after the students had graduated. The three sets of data are all connected to the same 10 students.

The Lifelong Learning journal entry asked the following questions of the graduates: 1) What does it mean to be a lifelong learner? 2) In what ways do you anticipate the field will change during your career? 3) Do you feel you embrace the concept of lifelong learning? Why or why not? 4) Discuss two ways you can demonstrate lifelong learning (within engineering or parallel to it).

The prompts from the Metacognition Memo start with this statement: **One of the important elements of learning is "regulating for the future." This takes place at the end of a learning cycle. The learner takes a step back and evaluates their learning processes, then identifies actions that can be taken to make future learning more effective and efficient.** The prompts that follow are: 1) In 1-2 paragraphs, describe your learning process. 2) How have your learning processes changed over the last 6 months? 3) What actions can you take now to make your learning more efficient and effective in the future?

After removing all identifying information for graduates, two authors conducted thematic coding to identify the lifelong learning attributes. Once they reached a consensus on the identified themes, each theme, and its combinations were further refined through data interpretation and supported with quotes that captured the unique perspectives of the graduating students.

2.2 Fostering a life-long learning mindset - results

The analysis identifies common themes of lifelong learning: curiosity and a growth mindset, adaptability to industry changes, seeking out new knowledge and experiences, multidisciplinary learning and broad skill development, reflective practice and self-improvement, collaborative learning and mentorship, and taking action toward learning.

- Curiosity and a growth mindset: Students emphasize that lifelong learning is driven by curiosity, a desire to improve, and a recognition that learning never stops. Quote 1: "To be a life-long learner means that as you continue in your career, hobbies, and life, you are always absorbing new information." Quote 2: "If you think you're already an expert in something, you will never progress beyond your current level of understanding."
- Adaptability to industry changes: Students acknowledge the need to stay current with evolving technologies, industry trends, and engineering practices. Quote 1: "Being a lifelong learner is about two key factors: Adapting to industry's inevitable changes and your own curiosity." Quote 2: "As technology becomes more advanced, what we learn now will become less useful. In order to be a successful engineer, it is important to invest time into learning over your career."
- Seeking out new knowledge and experiences: Students actively pursue learning beyond formal education, engaging in independent study, attending conferences, and exploring different disciplines. Quote 1: "Attending different conferences and presentations is often where people share their experiences that are different than yours and you can learn from them." Quote 2: "I genuinely enjoy learning new skills, so I always make time to watch videos or read about a new topic."
- Multidisciplinary learning and broad skill development: Many students wrote about how they embrace learning outside their primary engineering focus, valuing a well-rounded knowledge base. Quote 1: "I am a lifelong learner because I think it's better to be a jack of all trades." Quote 2: "I have learned about engineering, crochet, knitting, a little about chemistry, and a little about the medical field."
- Reflective practice and self-improvement: Students emphasize self-reflection as a tool for learning and improving their approach to problem-solving. Quote 1: "Even in the cases where I arrived at the incorrect answer, it helped me learn because I was able to see how the steps I took went wrong and how it needs to change." Quote 2: "The opposite of a lifelong learner is someone who thinks they know it all, so they don't learn new things and only try to protect their ego."
- Collaborative learning and mentorship: Students emphasize the importance of learning from peers, mentors, and professionals. Quote 1: "Continuing to gain wisdom from the mentor that I have now and eventually making myself available for mentorship in the future." Quote 2: "While some students mention mentorship and collaboration, there is relatively little discussion of networking and professional relationship-building."
- Taking action toward learning: Lifelong learning emerges as an active process that requires continuous engagement rather than passive knowledge absorption. Quote 1: "Not allowing yourself to become stagnant and having an open mindset to conversations and experiences outside your comfort zone." Quote 2: "Being a lifelong learner means continuing to pursue opportunities to gain new knowledge and skills even after 'finishing' a formal education."

2.3 Fostering a life-long learning mindset - discussion

The results of this analysis show the essential role of lifelong learning as seen through the eyes of graduates in a work-based learning model. From the discussion above on the Maastricht model, the student quotes demonstrate deep understanding through constructive learning, collaborative learning, and self-directed learning growth.

- Deep understanding through constructive learning - One of the most compelling insights from the student reflections is the emphasis on curiosity and a growth mindset, which drives a deeper understanding of subject matter beyond memorization. These findings suggest that when students engage in lifelong learning, they take an active role in knowledge acquisition, forming well-founded opinions on what is valuable and how to seek out new knowledge. Students expressed that seeking out new knowledge and experiences—whether through conferences, independent research, or cross-disciplinary exploration—helped them understand concepts at a fundamental level rather than merely recalling information for exams. This aligns with the idea that lifelong learning enhances retention and application of knowledge, as students are continuously reinforcing and contextualizing what they learn.
- Learning as a social and collaborative process - A recurring theme in student reflections was the importance of collaborative learning and mentorship, reinforcing the idea that engineering knowledge is shared in a professional environment. Students' discussions of mentorship and collaboration show how they appreciate how exchanging ideas and receiving feedback helps them refine their technical, design, and professional learning domains. The quote, "Continuing to gain wisdom from the mentor that I have now and eventually making myself available for mentorship in the future," demonstrates an awareness that learning is a continuous process driven by community engagement. Additionally, students acknowledge the value of interdisciplinary knowledge exchange, recognizing that engineers benefit from understanding perspectives beyond their immediate technical discipline. However, a notable gap emerged in student reflections regarding networking and professional relationship-building. While many students engaged in mentorship and collaborative learning, fewer explicitly mentioned active efforts to develop professional networks. This should be studied further and used as input to the continuous improvement process of the program. Ultimately, these findings support the claim that engineering learning extends beyond the classroom, with students benefiting significantly from social, collaborative knowledge construction.
- Building lifelong learning ability through self-directed growth - The theme of taking action toward learning aligns strongly with Sheppard's (2009) helical learning cycle, which emphasizes the progressive development of self-directed learning abilities. The results illustrate this progression well. The students recognize that learning does not end with graduation and that they must take active steps to seek out new knowledge, skills, and experiences. Furthermore, students demonstrate multidisciplinary curiosity, with some expressing an interest in fields beyond engineering, such as business, medical science, and even creative disciplines. However, an area for potential improvement is ensuring that students not only develop motivation for self-directed learning but also structured habits and strategies to sustain it. Some reflections suggest that without external guidance, students may struggle to maintain consistency in their learning efforts. These findings reinforce the claim from above that lifelong learning is a developmental process, with students continuously refining their ability to direct their own learning in meaningful and effective ways.

3 Impact on industries – workforce skills development

3.1 Impact on industries – workforce skills development - methods

The research in this section aims to discover the impact of graduating students' workforce skills development in this work-based learning program. Research Question: In what ways do graduating students of the work-based learning program add value to industry partners as perceived by graduating students and co-op supervisors?

Data was gathered from a written reflection assignment from graduating senior students and from co-op supervisor feedback that was provided directly to the program. All data was accessed and analyzed after the students had graduated. The two sets of data are separated from one another as supervisors did not have access to the student reflections, and the students were expected to turn in their reflection assignments prior to accessing the comments and feedback provided by their co-op supervisors.

The reflection assignment focused on the professional identity of students and recognized that their identity may shift throughout their education and life. They were asked to respond to multiple prompts that described their professional identity and how it has recently changed. One of the prompts had students respond to the following question: What are the top three assets you possess that allow you to bring value to a company? The responses to this prompt were used for this study.

Co-op supervisors were asked to respond to the following prompts for the supervisor's feedback. What are some of this student's strengths? What are some areas this student could improve in? What kind of value does this student add to the company? What comments do you have about the student's ability to work collaboratively with others? Is there anything else that you would like to add? Lastly, supervisors were asked to rate the student's overall performance on a scale of 1-5; 1 – not acceptable, 2 – needs improvement, 3 – acceptable, 4 – desired, and 5 – exceeding expectations.

Once the identifying information for all graduates and co-op supervisors was removed, two of the authors thematically coded all data to identify all value-added assets and skillsets that the graduates possess. The authors assigned "G#" as pseudonyms to each graduate to be able to cross-reference their reflection responses and their respective supervisor's comments. Once a consensus was reached for all identified themes, each theme and combination of themes were further defined through the interpretation of data and by using quotes from the unique perspectives of the graduating students on co-op and their co-op supervisors.

3.2 Impact on industries – workforce skills development - results

The total list of unique themes from graduating students' responses to the written prompt includes strong communication, willingness to learn, hands-on work, problem-solving, adaptability, curiosity, strong engineering knowledge, networking, learning from others, work experience, professional attitude, understanding, persistence, empathy, willingness to take on all types of work, ability to ask good questions, ability to seek feedback from others to improve, work ethic, teamwork, resourcefulness, idea generation, resilience, and quick to learn. Although many graduating students simply created a list of items in response to the prompt, there were three who provided further context for a total of seven themes. These quotes help to further define the following seven themes, while the rest are connected to the results from the supervisors' perspectives.

- <u>Willingness to learn</u>: "I am a learner. I have always had a strong desire to be challenged and learn from new things and experiences which means I will constantly be growing and learning from people and experiences" (G3).
- <u>Problem-solving</u>: "I have developed this through working on long term projects where I have been able to see the design process through" (G2).

- Adaptability: "I don't always have work to do on my projects, so I have learned to converse with other engineers and have developed a wide range of skills to be able to work on a variety of different project to remain billable" (G2).
- Curiosity: "I have learned to develop questions in a way that enables me to conduct research on my own to find solutions. Instead of going to another engineer right away, I can research and develop my own thinking on a problem, and then converse with another engineer to find the correct solution" (G2).
- Willingness to take on all types of work: "Willingness to help and assist with any project no matter the task, and willing to learn what it takes to complete it" (G6).
- Ability to ask good questions: "Anytime something looks off on a plan I raise a question and ask about it because it could look off because of my lack of experience or perhaps there may be something wrong with it" (G6).
- Ability to seek feedback from others to improve: "Before I show a finished product to a supervisor I try to ensure that I did not miss any parts and it is completed to the best of my abilities. I then ask to see if there is anything I should improve and be mindful of the next time I perform a similar task" (G6).

The results from the co-op supervisors' feedback provide a unique industry perspective on students' workforce skills development. Supervisor responses were first categorized by each graduate and then categorized by each identified theme. The themes were identified by the authors and were used in combination to summarize the findings. The combinations of themes include innovation & problem-solving, operational improvements & efficiency, workforce skill levels & preparedness, work ethic & initiative, collaboration & teamwork, and company integration & long-term impact. The final theme is professional growth & development, and it is regarding the answer to the prompt about student improvement areas.

- Innovation & problem-solving: The comments within this theme highlight the student's ability to identify problems and potential improvements, provide solutions to problems, and an ability to bring a fresh perspective to engineering problem-solving. One supervisor stated that one of the students on co-op was "amazing at figuring out things to improve and then figuring out how to make it happen" (G8's Supervisor). Another stated that a co-op student "provides fresh thinking/perspective and a positive attitude towards work and engineering problem-solving" (G1's Supervisor).
- Operational improvements & efficiency: Productivity, efficiency, and company workflow were all captured by the comments from supervisors and are used as words to help describe this theme. One supervisor stated that "[G4] has been able to quickly learn [Company E] practices and put them to work" (G4's Supervisor), while another stated that their co-op student "was always ready to work across the business, with operations, assembly, manufacturing engineering, and more" (G1's Supervisor). A third supervisor stated that "with [G7] as an added resource being able to setup and run the various engineering tests we have on our prototypes and designs allows for faster turnaround in the validations. This also allows the other engineers to focus on other project deliverables while she is gathering the data" (G7's Supervisor).
- Workforce skill levels & preparedness: Students on their engineering co-ops show up equipped with the skills to deliver valuable work from early on in their time at the company. One supervisor stated that the student on co-op for them is "willing to take on any tasks and take ownership of them" (G10's Supervisor). Another said that "after [G4's] training period, I was able to trust her to perform work with minimal oversight, and I was certain that she was doing it with integrity and accuracy" (G4's Supervisor). Another provides evidence of preparedness through the form of technical competence as "[G2]'s strengths include his ability to understand new concepts and apply them to tasks and overall

knowledge of his work. He is motivated and great at communicating his needs, questions, and progress" (G2's Supervisor).

- Work ethic & initiative: Students show up in their co-ops ready to make an impact. They are motivated to make a good impression and are willing to put in extra work to show others around them that they care about their work. One supervisor stated that the student on co-op is "hard-working and motivated to make the team and client successful" (G2's Supervisor), and another stated that their student on co-op is "able to take on a wide variety of tasks, puts in the work to understand the project and get it to completion" (G10's Supervisor).
- Collaboration & teamwork: Students arrive on the job ready to work alongside all kinds of people in the engineering field. They have experience leading and contributing to teams of various sizes. This was the most discussed theme for graduating student supervisors, as it included 12 feedback comments for the 10 randomly selected students. Some made claims that the graduating student they work with is a "great addition to the team" (G3's Supervisor; G6's Supervisor). Others stated that they are "easy to work with" (G5's Supervisor) and they "work well with others" (G7's Supervisor; G8's Supervisor). An ability to seek feedback is also highlighted as a part of their collaborative work. One supervisor said, "[G3] continues to work with other employees and manufacturing engineers. She is earning the respect of her peers and supervisors. She listens to her peers when advice is given and applies it when needed" (G3's Supervisor). Value and effective communication skills are addressed in this theme. One supervisor said that "[G8] has added a great deal of value on a personal level with almost everyone and also on a company-wide level" (G8's Supervisor); another stated that [G10] "doesn't have an issue reaching out to people and getting the information he needs" (G10's Supervisor), and another said "[G6] works well with everyone and has very good communication skills" (G6's Supervisor).
- Company integration & long-term impact: Various students have made a positive impression on their company and will continue to make a long-term impact as companies look to hire them full-time upon graduation. As one supervisor stated, "We are fortunate to have had [G6] as part of the team these past few semesters and are happy he has chosen to start his career with [company A]" (G6's Supervisor). Another said, "[G4] has been very pleasant to have as a co-op, and I am excited to be adding her to our team as a full-time engineer" (G4's Supervisor). Many students have also made significant contributions to the co-op programs that companies offer. One supervisor said, "[G3] has been a great addition to the [company B] team. Her feedback during the training process has been invaluable, improving the program" (G3's Supervisor).
- Professional growth & development: One of the prompts specifically asked supervisors to provide areas where students could improve. As a result, a few of the areas that were identified were related to boosting confidence, developing relationships, and furthering knowledge of specific company processes or products. One supervisor said that "she does need to start being a bit more confident in the work she's doing, to trust her knowledge and experience. There is a bit of hesitancy sometimes in explaining what is occurring, but I think a lot of that will come with experience as well" (G7's Supervisor). Another said, "[G4] could work on furthering her knowledge in medical device packing. We are working to get her enrolled in further training seminars" (G4's Supervisor).

The remaining results stem from the supervisors rating the performance of students on the job. Two of the ten students received a rating of 4 – desired, and the remaining eight of the ten students received a rating of 5 – exceeds expectations. The ratings were found to be reflective of the overall written feedback provided to each student.

4 Summary – insights on the transformative potential of work-based learning

This study provides a comprehensive analysis of the IRE Bell work-based learning model, which integrates academia, industry, and community engagement to enhance engineering education, support workforce development, and contribute to regional economic resilience. Focusing on its synergistic effects in a rural region of the upper Midwest of the United States, the study examines how immersive, real-world learning experiences prepare future engineers to address complex industry challenges while also benefiting local industries and communities.

As shown above, the findings indicate that students in the program develop key lifelong learning attributes, including curiosity, adaptability, multidisciplinary learning, reflective practice, and collaboration. These qualities align with the Maastricht PBL principles and Sheppard's (2009) helical learning cycle, showing that work-based learning fosters deeper understanding, improved retention, and active knowledge application. The model places students in a social and professional learning ecosystem where they gain hands-on experience, work alongside mentors, and apply theoretical knowledge in practical contexts, reinforcing learning as an active, socially constructed process.

Beyond personal and academic growth, the model demonstrates significant industry impact. Co-op supervisors consistently highlight that students contribute meaningfully in problem-solving, operational efficiency, teamwork, and innovation, with most graduates exceeding performance expectations and many transitioning into full-time roles. Employers also emphasize the value of students' initiative, adaptability, and willingness to take on complex engineering tasks, reinforcing that work-based learning not only prepares students for industry demands but enables them to make immediate contributions to their organizations.

A defining feature of the IRE Bell model is its emphasis on community engagement and the development of professional networks. By embedding students within a network of mentors, peers, and local industry partners, the program fosters a collaborative learning environment that supports both individual and collective growth. The program extends beyond the workplace—students actively contribute to local industry needs, reinforcing their role in regional development and creating a sustainable talent pipeline that strengthens the community. This integration between students, industry, and local stakeholders ensures that learning remains relevant, impactful, and mutually beneficial.

The alignment between student reflections and employer feedback provides strong validation for the effectiveness of the work-based learning model. Students recognize their growth in problem-solving, adaptability, and teamwork, and supervisors confirm that they excel in real-world engineering roles, integrating seamlessly into teams and taking initiative in projects. Many employers express confidence in students' abilities to continue growing professionally, contribute fresh ideas, and enhance company operations. This convergence between student perception and industry validation demonstrates that work-based learning is not just beneficial for students but an asset for industry as well.

The IRE Bell work-based learning model exemplifies the transformative power of integrating education with professional practice and community engagement. By placing students in real-world learning environments, fostering mentorship, and encouraging collaboration, the model cultivates engineers who are not only technically proficient but also adaptable, reflective, and self-directed learners. The strong alignment between student learning experiences and employer feedback reinforces that this approach produces workforce-ready engineers who make meaningful contributions to industry and community development.

Moving forward, the authors intend future research to explore ways to further enhance professional networking, assess the long-term career trajectories of graduates, and expand the model's scalability to diverse regions.

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