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Design-Based Research: Students Seeking Co-Op in Refined Educational Model

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Dennis Rogalsky is excited to be part of the faculty for the IRE Bell program and share in this innovative approach to engineering education. Dr. Rogalsky's degrees are in chemical engineering and he has twenty years of industry experience providing process control and automation solutions in petrochemical facilities. His career has blended educational and engineering experiences and he looks forward to teaching and research opportunities with the IRE Bell program and Minnesota State University, Mankato. Dennis is a licensed Professional Engineer in the state of Washington.

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Abstract
This research paper continues a longitudinal implementation of a design-based research (DBR) study and implementation for a new co-op centric educational model. This is a benchmarking study by the university program. Two iterative cycles take place simultaneously in the DBR study and interface to provide knowledge to one another. One cycle is the design of a new program, the other cycle is the research study. In this study, the research cycle includes literature review, data acquisition, analysis, evaluation, and findings. Out of the findings come recommendations for continuous improvement in the program design.

In this paper, the new model as well as the research method are described and results are presented for the first improvement cycle of the program. The data analysis shows improvement trends and identifies findings for the program regarding student attainment of the co-op. It identifies that successful position acquisition is closely aligned with career-fair contacts and connections through students personal, professional or Bell program networking. More findings are presented and future steps for both the program design and the research study are recommended. The findings of the research for the first and second cohorts inform the program for continuing to improve the experience and success of future cohorts.

I. Design-Based Research Method

The curricular development work for this project-based learning (PBL) program began in 2016 [1] utilizing design-based research (DBR) as the methodology for both design and research. Design-based research (DBR) was adopted as the methodology to 1) address learning theories, 2) to study learning in context, 3) to develop measures of learning, and 4) to contribute to new designs and learning theories [2] for the program development. The work incorporates the four phases of DBR identified by Kolmos [3]: *design*; *implementation; data collection and analysis;* and *findings and conclusions*. The DBR phases were adapted and combined with Andriessen's [4] dual purpose of DBR model as illustrated in Figure 1. The focus of the *program design* is *progressive refinement* through the problem statement; defining the design and learning objectives; planning (project management) of the curricular design, development of the curricular ideation and selection of a design for initial implementation; and ultimately a continuously reformed model with a curricular model improvement process. The focus of the *research design* is to establish the research questions; identify the learning theories applicable to the research work; design of the research work that influences the curricular implementation and improvement; and ultimately to disseminate what is learned and add to the body of knowledge on engineering education. This DBR approach also reflects Kolb's [5] four stages of experiential learning (experience, reflection, conceptualize, and test) as the program developers, faculty, and students learn together through each cycle of development.

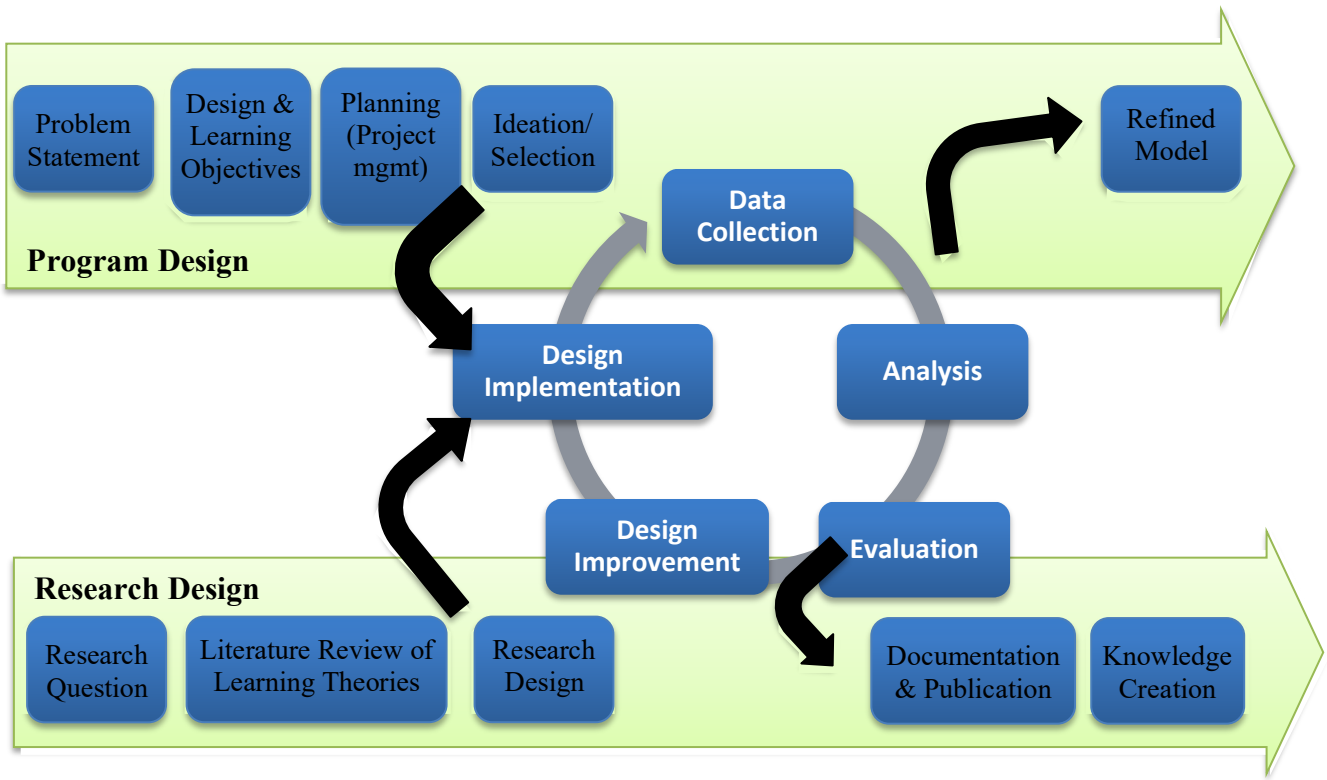

Figure 1. Adapted DBR Process Cycle

Previous iterations were focused on how the curricular element would be developed [1], how students and faculty members viewed the new curriculum [6] and how the first cohort of students experienced the attainment of their first co-op placement [14]. This paper will look at how the second cohort of students experienced the attainment of their first co-op placement following program improvements from the first cohort research. For this second iteration of the program development, we repeat the research question of: "How do Bell program student engineers experience the attainment of their first co-op placement?" In the data collection section below, the student experiences, reflections, and inputs have been collected and analyzed. Improvements have been put in place and ideas are available to draw on for conceptualizing future iterations.

II. Model Description

This new co-op centric educational model is an adaptation of two emerging world-leading engineering educational models, as recognized by a 2018 MIT report [7], Charles Sturt University (Australia) and Iron Range Engineering (Minnesota). Adapted from Charles Sturt model is the co-op experience where students spent an initial on-campus period and would then combine co-op work placements and on-line learning all the way to degree completion [8]. Adapted from Iron Range are the curricular strategies that empower a graduate with a balanced set of technical, professional, and design capabilities [9]. In this new model, students complete their lower-division pre-engineering requirements at a community college anywhere in the U.S., then transfer into the model for a one-semester intensive on-ground experience, the engineering development phase (EDP), where they acquire the self-directed learning and professional skills

needed to thrive in a co-op placement. With COVID-19, students are also completing the one-semester intensive EDP experience remotely in their home communities; this is planned to continue as an option into the future. Upon completion of the EDP, students enter 24 months of co-op placement/on-line learning, returning to the institution after 12 months and 24 months for one-week examination periods (See Figure 2.).

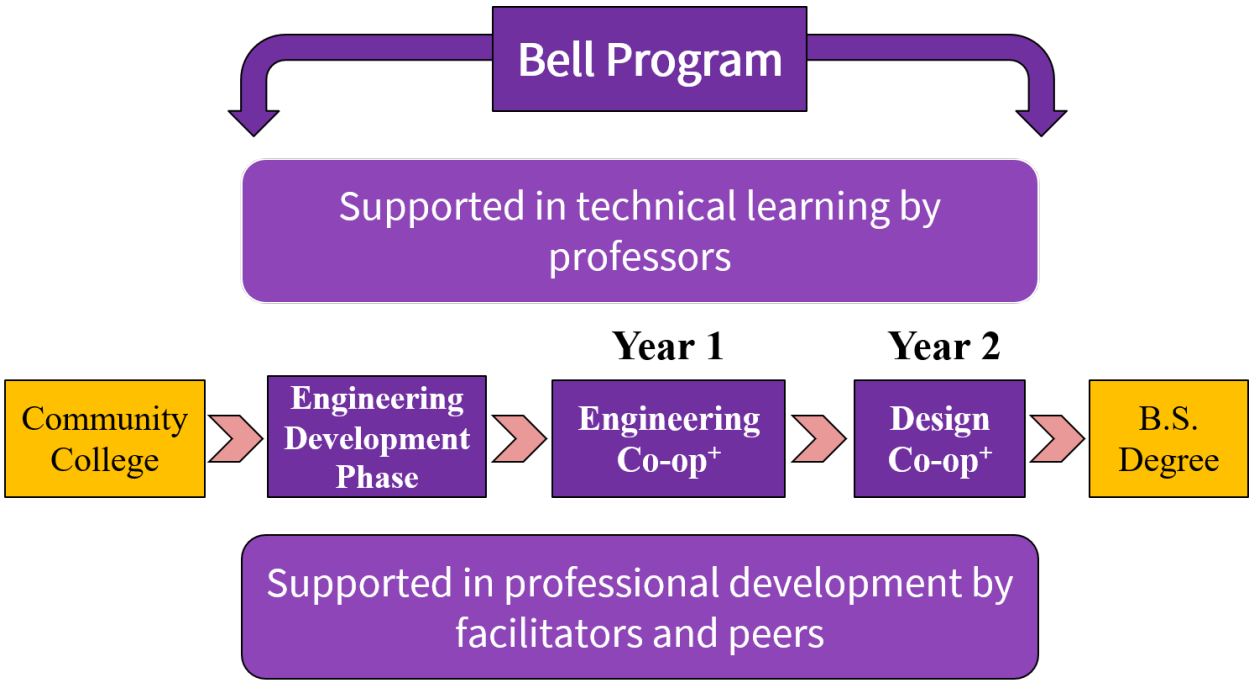

Figure 2. Co-op Program Model

The motivations to start the new program come from a desire to move towards work-based learning, empowering student engineers to gain more practical experience while funding a larger percentage of their own education than through a traditional engineering education. The evolution of learning technologies empowers the attainment of this goal more so today than in the recent past. A further motivation is developing a model that can potentially impact the lack of diversity in the engineering profession. The demographic of community college students is considerably more diverse than the engineering profession [10] and the new program makes an engineering education more accessible to community college students.

The EDP for Cohort 1 was from August to December 2019. The EDP for Cohort 2 was from August to December 2020. The EDP for Cohort 3 started in January 2021. There are many aspects to describing the model; relevant aspects to this research paper are described in the following sections.

Engineering Development Phase

The EDP is an intensive experience focused on development of the individual in four domains: design, technical, professional, and job-search.

Design learning happens with an engineering project from an industrial client, serving as the central component to the student experience, as is done in the Aalborg University (Denmark) model of PBL [11]. Students undertake four, one-month project design "sprint" cycles. During these "sprint" cycles, they practice an iterative engineering design process progressing from problem definition through scoping, research, ideation, modeling, testing, and design evaluation; all while making several verbal presentations and going through several iterations of written technical documents.

Technical learning happens in the Iron Range Engineering model whereby students complete 32 one-credit courses (16 core, 16 advanced elective) [12] across the whole program. Eight of these courses take place during the EDP with students taking two courses per block across four one-month blocks. To provide a scaffolded experience for the students, the first block courses are similar to the traditional model of learning that students have experienced. In each successive block, scaffolding is removed as they transition towards being self-directed managers of their own learning by taking on more responsibility in the learning process. Students write learning plans; develop questioning techniques; accumulate knowledge with an eye towards long-term reflection; apply engineering principles to multiple open-ended problems; and use reflection and metacognition as ways to promote technical knowledge transfer [13].

Professional learning happens across multiple domains. Professional responsibility is modeled and practiced throughout as timeliness, respect, appropriate dress, appropriate language are all made explicit with continuous feedback coming from faculty and staff. Teamwork skills are provided in seminars and practiced in design teams. Multiple workshops per week address topics such as: inclusion, ethical action, leadership, reflection, management, happiness, life-work balance, overcoming adversity, and communication. Each week during the EDP students write three one-page learning journal entries, most of which are reflective prompts from some aspect of professional learning. These student reflections related to professional capabilities continue throughout the program.

Job-search learning happens through ongoing career development training focused on locating and acquiring engineering jobs. This training is focused on deeper understanding and practice in the following key areas: LinkedIn Profile, Resume, Cover Letters, Elevator Pitches, Search Strategy, Networking, Interviewing and Follow-up. The training helps students develop, practice and continuously improve their own portfolio of career tools. As an example, during practice interviews students are interviewed by a panel of faculty and other students. Thus, they not only receive performance feedback but can learn from the successes and failures of others and the process of giving feedback. Finally, students send thank you communications and receive feedback on the substance and form of this communication. A graphical depiction of the *jobs package* elements is shown in Figure 3.

Figure 3. Bell program job search graphic

Co-op Phase

During the co-op phase, student engineers work 40-45 hours per week as engineering apprentices for a firm that employs engineers. The university program employs "facilitators" who are bachelors or masters educated engineers with engineering experience. These facilitators are the conduit between the program and the student as well as liaisons to the students' supervisors at the company. Each week, the student and facilitator have verbal conversations over Zoom or telephone. These mentor-type conversations address work experiences, learning opportunities, continuous improvement, and result in much reflection. In addition to the weekly conversations, students spend 10-12 hours per week completing school-related work. Half of the time (5-6 hours) are spent completing technical learning courses taught by the program's PhD professors. The other half (5-6 hours) are spent in on-line professional development workshops, writing technical design papers, and completing written reflections on the wide-variety of learning experiences taking place on the co-op placement across the professional, technical, and design domains.

Twice during the co-op phase, usually at 12 and 24 months, students will have an examination period where they undergo a variety of technical examinations and give multiple professional presentations in both a Ted-talk type format and traditional engineering presentation format. The second exam period is planned to immediately precede graduation.

Accreditation Details

The Bell program is accredited as an extension to its parent program's current accreditation. The program and student learning outcomes are exactly the same as the parent PBL program which has twice been accredited in its ten year existence. The outcomes are extremely well aligned with

ABET outcomes. The new program obviously has a different delivery modality, but the standards of student outcome achievement are the same.

Focus on Co-op Placement

This research paper focuses on the process and success for student acquisition of co-op placements with comparison between Cohorts 1 and 2. For the initial cohort, the program developers expected that the process would be primarily related to the number of applications. After our research results showed Cohort 1's success was more dependent on personal connections with a company, networking with companies was given a strong focus throughout 2020. Networking was a stronger focus in the training for Cohort 2 students and they had greater opportunities to connect with companies through Bell Program sponsored career fairs. Part of this research will look to identify if the program changes made from the first research resulted in tangible improvements for Cohort 2 co-op placement.

III. Research Study

Research Question

The research question focuses on the second cohort of students for the program in asking; "How do Bell program student engineers experience the attainment of their first co-op placement?"

Data Collection

The data collection section provides numbers on the effort and results of the second cohort of students. The numbers were tabulated from survey responses at the end of the EDP; 28 of the 31 Cohort 2 students responded. The quantitative data is supplemented by opinions and feedback that were collected by one of the authors through interviews of the students and program staff at the end of the EDP semester. Additionally, some comparison between prior Cohort 1 data [14] and current Cohort 2 data will be made to look for improvement trends. The research protocols applied were submitted to and approved by the Institutional Review Board, IRB.

In Table 1, the data for the EDP semester co-op job search is presented for the 28 students that responded to the survey. These are results at the end of the EDP semester. As a quality check; the numbers have been reviewed with the program facilitators to ensure alignment with their job placement tracking for the semester.

Table 1. Cohort 2 Co-op Placement Data

	Total	**Average**	**Min**	**Max**
Job Applications	1046	37	9	97
Follow-up Connections	219	8	0	23
Interview Requests	60	2	0	8
Offers Accepted	23	n/a	n/a	n/a

Pay Rate ($/hr)	n/a	19.9	13.0	25.0
Housing Allowance	Part of 8 offers	n/a	n/a	n/a

In Table 2, the data for the EDP semester co-op job search is presented for the 28 students. Data is broken out between those successful in finding a co-op position by the end of the EDP semester, 23 of the 28 students, and those still looking at that point, 5 of the 28 students.

Table 2. Program Cohort 2 Co-op Comparison Data

	At End of EDP: Co-op Achieved (23/28)					**Still Looking (5/28)**			
	Total	**Avg**	**Min**	**Max**		**Total**	**Avg**	**Min**	**Max**
Job Applications	863	37.5	9	97		183	36.6	25	70
Follow-up Connections	209	9	0	23		10	2	0	8
Interview Requests	54	2	0	8		6	1	1	3

Interviews were done with ten Bell program students selected by staff at the end of the EDP semester to gather feedback on the co-op job search process. They were conducted by a program researcher removed from the daily interactions with students and facilitators. The interview questions focused on three aspects of the process of obtaining a co-op or internship placement: 1) the planned process obtaining a co-op/professional placement, from personal and programming perspective, 2) opportunities for improvement for future students, and 3) personal opportunities for improvement for the student as an individual.

One main observation stood out from the interviews; the students that had a co-op placement had obtained them through personal network connections or job fairs. The main themes that emerged from the experience and improvement interview questions are given below for both groups.

Summary of Student Experience in Co-op Attainment Process

(Consistent Theme: noted by 9-10 students, Common Theme: noted by 5-8 students)

1. *Co-op Placement Process Experience Trends*
    - Consistent themes
        - All students expressed the importance of and/or appreciation for job search training activities and workshops prior to and during the EDP
        - High value was noted for the program's clear and consistent focus on internship/co-op applications by students and the program's outreach activities/communication to connect students with companies
        - Importance of student professional networking to complement the internship/co-op applications
    - Common theme
        - Benefit of personal goal setting for applications

    - Value of tracking personal application process, both in regards to quantity as well as results
    - Recognition of the need to dedicate time for the application process

2. *Thoughts for Next group of students*
    - Consistent themes
        - The program should continue development of career fairs
        - Shift emphasis from quantity of applications to application quality, especially in terms of effectiveness in getting interview/offer
        - More application submittals and training taking place prior to the EDP
        - Developing students focus to be more on the development opportunity of internship/co-op and less focus on the location
        - Build stronger student understating of filters used by companies in automated resume review systems
        - Mixed reviews on current focus/usage level of LinkedIn by students in the application and networking process
        - Moving up job search elements so that job search process is well underway during the prime window for applications
        - Further development of students' individual co-op search strategy document. Elements are location, type of industry, etc. Biggest challenge is for students who are narrowly focused.
    - Common themes
        - More time spent on a regular basis to reflect on application process effectiveness to develop understanding of the following:
            1. Application approach effectiveness
            2. Progress of applications to achieve placement

In Table 3, comparison data is presented for Cohort 1 of 19 students and Cohort 2 of 31 students. As a primary change from the Cohort 1 research was having Bell program staff develop relationships with more companies hiring co-op students and hosting our own virtual career fairs, the final row of Table 3 looks at the number of students that obtained their first co-op position with these "connected" companies. The data presented is for each cohort at the end of their EDP semester; for Cohort 1 that was December 2019 and for Cohort 2 that was December 2020. The percentages listed for students finding jobs are in comparison to the total number of students in that cohort; shown in the header as 19 students in Cohort 1 and 31 students in Cohort 2.

Table 3. Program Cohort 1 and 2 Co-op Comparison Data

	Cohort 1 (19)	**Cohort 2** (31)
Job Applications (average)	35	37
Follow-up Connections (average)	5	8
Interview Requests (average)	2	2
Co-op Jobs Obtained	9 (47% of Cohort 1)	23 (74% of Cohort 2)

Jobs Connected to Bell Program Outreach	6 (32% of Cohort 1)	15 (48% of Cohort 2)

Analysis

The numbers in Tables 1 and 2 demonstrate that successfully finding a co-op position during the EDP semester is not correlated to the number of applications a student makes. Table 2 shows little variation in the statistics between the successful students and those still looking. This is a repeat of the finding from our Cohort 1 analysis [14]. The numbers in Table 3 show improvement for Cohort 2 students successfully finding co-ops and hiring by companies the Bell program has developed relationships with.

The interview responses show that students recognize the value of networking with the hiring company outside the standard application process, the importance of career fairs and the need to start early with their job search. The importance of career fairs is consistent with the 2019 survey by the National Association of Colleges and Employers showing employers consider career fairs the most effective recruiting technique [15]. The interviews indicate a need to continue to focus on training and quality applications while developing greater detail on how companies use applicant tracking systems. Interviews continue to support students developing broader co-op search criteria in this first search; not starting too focused in geographic location or type of work.

IV. Findings and Future Steps

The nature of this ongoing DBR study is to simultaneously provide knowledge for the design of the new program and at the same time contribute knowledge creation to the broader field of engineering education. The findings from our study of the first and second cohorts inform the program for continuing to improve the experience and success of future cohorts. The study shows that program development needs to improve students' awareness and skills for the multiple approaches to co-op placement. The current primary emphasis on applications develops students understanding of what skills and abilities they need to possess, but it varies by student how they understand and thus value and allocate time for the different approaches to co-op placement. Program development needs to facilitate this for incoming students.

The findings also inform the broader engineering community in regards to student attainment process in a co-op centric model and continued future steps for research. Co-op or internship experiences are often important to an engineer's first job and sometimes directly lead to the first job. Not only do these findings inform engineering education, but they are also guiding to employers. They have a role in the development of the next generation of engineers, in partnership with higher education, to not only provide the learning experiences but look at their own application processes and identify how they can be improved so that they truly reflect the skill, abilities, and diversity valued in the next generation of engineers.

Findings

1. Successful position acquisition is closely aligned with career-fair contacts and connections through students personal, professional or Bell program networking.

2. Students recognize the value of focused career development skills training prior to and during the Engineering Development Phase.

Future steps for the program

1. The program staff should continue to develop and sustain an extensive network of companies willing to interview students from the program.
2. The program needs to continue development and expansion of career-fair and student-company networking opportunities.
3. The program should continue to develop and improve on an explicit/consistent model to train and motivate students in their search for co-ops/internships.

Future steps for the research

1. Apply the same research method 12 months later when the program has implemented future steps and additional cohorts of students have reached the same point in their EDP job search phase.
2. Apply the design-based research method used in this paper to the Bell program's focus on developing a network of industry connections.

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