Financial Benefit of Workforce Development Projects in Engineering: Using Return on Investment (ROI) and Key Performance Indices (KPI) for Evaluation

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***Abstract*— This innovative practice full paper presents a novel ROI metric for engineering and technician work force development (WFD) programs along with complementary key performance indices (KPI's) derived from business financial measures. As many workforce development programs are funded by taxpayers, quantifying outcomes in terms of economic benefit is crucial for justifying their existence. Moreover, Pareto frontiers (boundaries of optimal solutions) are found that reveal inherent trade-offs between: (a) value to funding agencies; (b) value to students; and (c) cost effectiveness. These trade-offs depend not only on program performance but also on the chosen WFD approach. Practical application of the ROI metric to a leading, cross-university, multi-discipline, national WFD effort in microelectronics engineering that is funded by the US Department of Defense is included as a reference case. The utility of the metric for identifying tangible paths to higher ROI is shown for this program. Moreover, its ROI, cost, and student value are compared to alternate WFD approaches of scholarship and internship programs using Pareto frontiers. While the scope of this work is WFD programs in undergraduate and graduate education, the approach is even more general, which could point to further research in this area.**

Keywords*— *Organizational Assessment, Program Evaluation, Undergraduate Education, Graduate Education, Professional Development

I. Introduction

Sufficient quantity and quality of skilled and experienced workers are vitally important to economic security, public health and welfare, and political / military stability at national and local levels. Evolving and emerging markets and technologies; changing workforce demographics; and shifting political and regulatory environments are a few of the many dynamic factors that can cause misalignment of workforce availability and readiness to workforce demand [1]. Workforce development (WFD) programs can be effective solutions, and since funding in most industrialized nations is limited to 0.1 to 0.5% of GDP, it is important that monies be invested where cost effectiveness and returned value have been proven [2].

Therefore, quantifying WFD program performance in economic terms is vitally important to WFD sponsors, directors, and educators so that funding is secured and retained. As described below, prior methods required extensive evaluation data or introduced a myriad of value considerations. Such approaches create significant resource demands, time delays, need for certified and specialized skills, and points of debate as to the validity of the estimates. In contrast, this paper describes a novel set of WFD economic metrics (ROI and KPIs) that are easily calculated with minimal additional data, resources, or specialized skills. They can be used for proposal preparation, selection among competing proposals, process improvement, benchmarking, and close-out reporting. As such, the ROI and KPI metrics provide a common language connecting WFD sponsors, educators, and employers.

II. Background and Literature Review

Return on investment (ROI) is a well-accepted measure in use by over 2,000 organizations in manufacturing, service, nonprofit, government, and educational settings [3]. For any project, it is defined as:

$$ROI = (R - C) / C \qquad (1)$$

ROI's appeal as a business metric lies in its: (a) conceptual simplicity; (b) applicability to a broad range of ventures; (c) utility for project selection and improvement; and (d) ease of calculation *when the costs and returns are measurable and recorded*. In business, cost and return measurement is frequently made for legal compliance to generally accepted accounting principles (GAAP), thereby providing a basis for ROI calculation.

Unfortunately, returns of training and workforce development programs are infrequently measured. A well-known methodology for overcoming this barrier was proposed by Phillips [4]-[6]. It is built on a foundation of evaluation data, in much the same way that a business' ROI calculation is built on a foundation of accounting data. Moreover, Phillips proposed ROI calculation as a fifth level of evaluation [7], extending Kirkpatrick's four level model [8]. This paradigm has gained support within the American Society of Training and Development (ASTD), which offers Level 5: ROI Calculation certification courses.

Despite the prominence of Phillips' methodology, application remains limited. A 2019 survey of HR professionals at 53 companies showed 40% never and 40% rarely calculate the economic value of training offerings [9]. Ten years earlier, Cairns [10] reported very comparable results with only 18% of HR and learning professionals using ROI calculation methods. He ascribed this to two obstacles:

- ***Value Attribution:*** Lack of accepted methods for attributing business value based on training program data
- ***Learning Management Systems (LMS) Limitations:*** Inadequate measurements to support the accepted method for business value calculation

In the present work, leadership of the US Department of Defense (DoD) tasked the authors with ROI estimation for a large microelectronics WFD effort for undergraduate and graduate students, called SCALE (Scalable Asymmetric Lifecycle Engagement). The consortium had just passed into the first year of its production contract at the beginning of the 2023 US federal government fiscal year, having completed the prototype stage that began in 2020. Its scope includes over 50 employers, 22 universities, 20 academic majors, 850 students, and 100 faculty members across 5 different technical areas. Because the program operates on annual funding, an objective and defensible ROI estimate was needed within a few months of request.

While well established, the Phillips methodology was not feasible for this case due to two barriers:

- ***Scope:*** Measurement of pre- and post- training proficiency across a representative range of employers, roles, and individual knowledge, skills, and abilities would have required a significant level of resources not included in the contract. Moreover, Phillips recommended that ROI should only be calculated for a minority (about 5%) of training programs due the resources it demands [4]. However, calculating ROI on 5% of the program and claiming it represents the remaining 95% would have insufficient credibility with budgetary stakeholders.
- ***Available Time:*** As mentioned above, the time available for developing the ROI metric was a few months, with the expectation that it would be calculated for the first fiscal year of the production phase. This constraint affected time available for metric creation as well as data collection.

To overcome these obstacles, the authors developed a novel ROI metric that still complies with many of Phillips' criteria for an effective ROI process. These include [4]:

- Implementation which is simple, easy, and economical
- Foundation which is theoretically sound and supported by credible assumptions
- Applicability to a variety of efforts on a pre- and post-program basis
- Compliant to the standard definition of ROI (1) and including all program costs

The ROI metric presented below is a complementary approach to the Phillips methodology, each having its own area of application and target audience. The detailed Phillips methodology may be best used for individual training programs with ready access to pre- and post-training participants. In contrast, the authors' approach is amenable to large scale WFD efforts. Several opportunities for reapplication include the Defense Civilian Training Corps, Reserve Officer Training Corps, and several efforts funded under the Chips and Science Act [11]. Furthermore, the metric is focused on the needs of funding agencies and WFD directors, who must work together to create and execute WFD initiatives that make training and its educational evaluation efforts possible. In contrast, the Phillips model is more attuned to evaluators of established efforts that need to reframe evaluation results in financial terms.

The remainder of this paper is organized as follows. After introducing the novel ROI metric and KPI scorecard (Section III), its application to the SCALE WFD consortium is described (Section IV). In Section V, application to two other WFD approaches (internship programs and the SMART Scholarship program) is shared. Pareto frontiers are introduced that reveal comparisons of and tradeoffs within these three WFD approaches in Section VI. The utility of the metrics for process improvement are shown in Section VII, followed by conclusions (Section VIII) and plans for future work (Section IX).

III. Methodology

A. Foundations: Stakeholder, Period, and Placement

The starting point in applying (1) is to choose the ***stakeholder*** for the ROI calculation and the ***period*** for returns and costs. Since the funding entities are the program's sponsors and primary stakeholders, this is the option of first choice. Other options are possible and beyond the scope of this paper (e.g. WFD participants, general public, local economies). The chosen period should be meaningful to the stakeholder, and a fiscal year basis is amenable to government and industry. All stakeholder costs need to be accounted for, and total funding to the WFD effort is readily known from WFD budgets and account systems with few exceptions (e.g. in-kind contributions). On the other hand, calculation of returns is a greater challenge.

The primary objective of WFD programs is to deliver talented personnel, and returns are the aggregate value of each participant ***placed*** in the intended workforce. Since ROI is from the perspective of the funding entities, the definition of a successful placement should be negotiated with the program sponsors. For example, in the case of SCALE this was chosen to be students accepted into the program, graduated, and transitioned post-graduation to: (a) employment in the defense industry; or (b) enrollment in a graduate degree program.

B. Calculation of Returns

Armed with a definition of successful placement, the return is simply the sum of the value of each placed participant (student). This sum is over the same period used for cost calculations. Mathematically:

$$R = \sum_{i=1}^{nplaced} Vplaced_i \quad (2)$$

The value of each placed student is related to their unique combination of academic credentials and development prior to completion of the WFD program:

$$Vplaced_i = Vdegree_i + Vdev_i \quad (3)$$

Development value includes experience gained, special training completed, and authorizations received. It measures each student's readiness compared to an unexperienced student ("green hire"):

$$Vdev_i = Vexp_i + Vtrng_i + Vauth_i \quad (4)$$

To calculate the value of each student's academic credentials, we apply the accounting practice of book value, which states that at deployment, an asset's value equals its purchase price. We can consider the price as a series of payments equal to average annual starting salary plus fringes, for students of the same degree and field of study, times a number of years over which the student transitions from relying heavily on their pre-employment training to their post-employment experience. This can be written as:

$$Vdegree_i = SFfield,deg_i * Ybase_i \quad (5)$$

In the field of engineering, the values of *Ybase* can be taken as 5 years for a bachelors candidate, 3 years for a masters candidate, and 2 years for a doctoral candidate. Other assumptions can be made for other fields and degrees (e.g. associate degrees).

We extend this approach to (4), using the same average annual salary and fringes, crediting equivalent on-the-job experience for pre-placement work experience, special training, and authorizations received. Thus:

$$Vdev_i = SFfield,deg_i * (Yexp_i + Ytrng_i + Yauth_i) \quad (6)$$

A schema for estimating $Yexp_i$ and $Ytrng_i$ is shown in Table 1 and is based on a 1:1 ratio of contact hours to on-the-job experience.

The remaining term in (4) is $Yauth_i$, which is computed from:

$$Yauth_i = Yapply * Dno\_auth \quad (7)$$

Authorizations are permission to engage is certain work activities, and (7) recognizes that without such an authorization at the start of employment, the employee's ability to fully contribute to the employer is limited. Examples of authorizations are licenses to provide public services (e.g. professional engineering licenses) and security clearances. This term is only included in (4) for students that have obtained such authorizations before completing the WFD program.

TABLE I. SCHEMA FOR CALCULATING TIME EQUIVALENTS FOR WORK EXPERIENCE AND TRAINING

Type of Work Experience or Training	***Yexp [years]***	***Ytrng [years]***
3 Month Work Internship or Summer Undergrad Research	0.25	-
Semester of Undergrad Research	0.10	-
Year of Graduate Research	1.00	-
Year of Prior Relevant Full-Time Work Experience	1.00	-
3 Credit Hour Technical Elective Course	-	0.10

Return calculation is then the successive application of (2) through (7). It only requires knowledge of: (a) which students were successfully placed during the period; (b) each student's degree and field of study; and (c) each student's development activities – work experience, special training, and authorizations gained. While the structure of the calculations is specific to WFD in degree granting institutions, they are tailorable to any academic discipline and industry/government field.

C. ROI Metric and KPI Scorecard

Having calculated returns as described above and knowing total costs over the period, (1) can be applied to calculate ROI. While ROI is an important metric, it is not the only one of interest.

To that end, Table 2 shows a KPI scorecard of WFD metrics derived by analogy from common business measures. In each case, the objective is to increase the metric. For WFD efforts that deliver students with a range of degree levels and/or technical disciplines, it is valuable to add a metric for variation of percentage of students by degree versus target (e.g. percent of students with advanced degrees vs target percentage). An alternate approach is to have separate scorecards for each degree level and/or technical discipline. This is the business equivalent of targeting sales distribution by market or evaluating performance by business unit.

TABLE II. WFD KPI SCORECARD ANALOGY TO BUSINESS MEASURES

WFD Metric	***Quality Assessed***	***Equivalent Business Metric***
Return on Investment (ROI) [-]	Net Benefit / Cost Ratio	ROI
Number of Students Placed [-]	Placement Volume	Sales Volume
Placed Students per $100K Cost [-]	Capacity / Cost Ratio	1 / Unit Cost
Average Development Value of Placed Students [K$]	Student Development	Unit Gross Margin

D. Considerations in ROI Metric Calculation

A few important remarks about the ROI metric are now offered. Note that the only returns in the ROI calculation are those associated with the primary value of WFD efforts - to recruit, develop, and place talent in the intended industry. No account is made for secondary value such as economic growth, tax base, intellectual property, or best practice reuse. Although nothing precludes adding these terms as suggested by others [4], they were intentionally omitted to mitigate three issues below.

Gamesmanship: Secondary value estimates, often of intangibles, can give the impression of or opportunity for gamesmanship, undermining credibility of the ROI estimate and potentially inducing unwanted or undesirable activities that do not serve the goals of the program [12, 13].

Metrics – Mission Misalignment: Structure of the current ROI metric reinforces the WFD mission to recruit more students, develop them more deeply, and increase the percentage of participants placed in the workforce for each dollar spent – encouraging WFD leaders to 'do the right thing'. Without such alignment, metrics can drive actions counter to the mission [14].

The Attribution Problem: It has been argued that ROI must include only incremental value beyond the "do nothing" or "take no action" alternative [12]. While valid in theory, in practice it is quite difficult to determine whether a student would have entered the industry in the absence of the WFD effort. Since the value of the "do nothing" alternative is not affected by the WFD program, for a collection of WFD strategies or programs sharing the same goal, this term would not change their ranking by ROI such as shown in Section VI. Rather, it would create an offset between reported ROI values and the (presumed to be) true ROI values. The "do nothing" value also ceases to be of interest once stakeholders decide that "do nothing" consequences are no longer tolerable, and indeed this is the case for many WFD efforts.

IV. ROI and KPI Calculation For The SCALE Consortium

ROI and KPI calculation are now illustrated for the SCALE WFD consortium. Founded in 2020, SCALE is funded solely by the US Department of Defense for the purpose of meeting microelectronics personnel shortfalls within in the defense industry. A lifecycle engagement approach is employed, meaning that it includes K-12 outreach, engagement with undergraduate and graduate students, and continuing education for practicing professionals. In the coming years, program scope will extend to community colleges and faculty development. Present focus is on STEM professionals, especially engineering, computer science, and mathematics graduates.

The SCALE WFD approach to undergraduate and graduate students includes offering them undergraduate research, independent study, special curriculum, work internships, and graduate research opportunities to develop KSAs related to 5 different technical areas within the defense microelectronics industry, with 6 more technical areas planned in the next 3 years. Faculty mentoring, on-campus events, and a weekly seminar series are used to build community and technical expertise. A restricted access job board advertises openings across a network of government and industry partners. As mentioned above, a successful placement is defined as a SCALE student that either enters the defense industry or enrolls in graduate school post-graduation. While students are under no obligation to take these paths, about 75% of students do so. More detail on SCALE's approaches is available elsewhere [15].

ROI and KPI calculations below are focused on SCALE's undergraduate and graduate efforts for FY23 (01 April 2023 – 31 March 2024). For this scope and period, DoD funding totals \$15,277K, which is the cost term in (1). Returns are associated with the 127 students successfully placed between 01 July 2023 and 01 June 2024. This period is offset from the fiscal year since costs incurred during FY23 supported students that graduated in August 2023, December 2023, and May 2024, and the majority of students graduated in May. Student data for ROI and KPI calculation was taken from the SCALE Web App, which is a browser-based interface to a Microsoft Azure database. Data collection for the Web App was through a combination of student self-reported data, post-graduation plan surveys, and LinkedIn profiles. The database provided information required to calculate terms in (4) except for the special training term. This is a growth opportunity, as certifications are to be formulated and awarded by SCALE within the next few years to reflect completion of specialized training and acquisition of associated knowledge, skills, and abilities (KSA).

Average annual starting salaries and fringes by degree and field of study are also required. Salary data was collected from various public sources and is summarized in Table 3, exclusive of fringes which are assumed to be 30% of annual salary. For SCALE, approximately 50% of students major in Electrical & Computer Engineering, with the remaining 50% spread across numerous fields of study.

For SCALE, the authorization term in (4) and (7) is related to whether the placed student received a security clearance prior to their post-graduate employment. If not, this takes approximately six months, and for that period it is assumed the value of the new employee is reduced by 50% since they are not able to complete classified work. Applying (7) shows that a pre-placement clearance is equivalent to 0.25 years of on-the-job experience. Currently only a few percent of placed students report that they hold a clearance.

Using the data and assumptions mentioned above, the FY23 ROI for SCALE is 3.57; placed students per \$100K is 0.83; and the average development value per placed student is \$86K. This completes entries in the KPI scorecard of Table 2, which are contextualized in Section VI.

V. ROI and KPI Calculation For Alternate WFD Approaches

The ROI and KPI metrics defined above are applicable to differing WFD approaches. To illustrate this, the following subsections detail calculations for two alternate strategies to SCALE, which are an internship program and the SMART Scholarship program.

TABLE III. Average Annual Starting Salaries [K\$] (Exclusive of Fringes) – Partial List of Common Majors

Major	*BS Degree*	*MS Degree*	*PhD Degree*
Electrical & Computer Engineering	71.8	100.7	110.4
Material Science	56.5	79.1	96.3
Computer Science	80.5	91.2	-

A. ROI and KPI Calculation – Internship Program

Summer internships are typically offered by a company or government agency to students, with the desire to recruit them for full-time employment. Here, the stakeholder is the employer, and a successful placement is defined as post-graduation employment of the student with the organization. Average salary for a summer intern for 4 months is $11.6K [16] and with a 30% fringe rate the total cost is about $15K. For simplicity, the ROI calculation period is taken to be one year.

The probability of the student joining the employer post-graduation was estimated from a sample of 30 student records randomly selected from the SCALE Web App for students who: (a) graduated; (b) took employment post-graduation with a known employer; and (c) completed at least one internship during their undergraduate studies with a company or governmental agency. The number of unique combinations of students and internship employers was 55. Thus, students are gaining work experience with about two different employers. Moreover, there were only 6 combinations where the student was employed post-graduation at one of the organizations they interned with, for a placement rate of 6/55 = 11%.

Taking the placement rate of 11% into account, the cost per student placed is then $15K/0.11 = $136.4K. Alternatively, the KPI of placed students per $100K cost is 0.73.

Since internships are focused on undergraduates, we can estimate the remaining KPIs and ROI by assuming the student is a BS graduate in Electrical and Computer Engineering with two internships and no special training or authorizations gained. Assuming the same annual starting salary (see Table 3) and a 30% fringe rate, it can be shown from (6) that the average development value of placed students is $46.6K and from (3) and (5) that the average value of each placed student is $513.1K. Then, applying (1) gives an ROI of 2.76.

B. ROI and KPI Calculation – SMART Scholarship Program

The SMART Scholarship program [17] is funded by DoD and therefore they are the stakeholder. After graduation, the awardee is required to work for DoD for at least as many years as they were on scholarship. Successful placement is defined as the student working in DoD after graduation and it can be further assumed that placement rate is approximately 100%. In 2023, the distribution of scholarships was 50% bachelors, 12% joint bachelors+masters,14% masters, and 24% doctoral candidates.

Awardees receive full tuition ($16K to $42K), a stipend of $30K to $46K per year, health insurance allowance of up to $2.5K and a miscellaneous allowance of up to $1K per year. A summer research experience and mentor are also provided. Thus, the average annual cost per year for a SMART Scholar is $70.5K ($29K tuition + $38K stipend + $3.5K fringes). The total cost of a SMART Scholar is this annual rate times the number of years the student is on scholarship.

We assume that during the summer, undergraduates do an internship and graduate students continue their research toward their advanced degree. Values in Table 3 for Electrical and Computer Engineering graduates were assumed along with a fringe rate of 30%.

Using the information above and the equations previously discussed, ROI and KPIs for different types of SMART Scholar participants were computed (see Table 4). Also included are aggregate values which correspond to the current distribution of SCALE students by degree and year in program. This distribution was chosen so that comparisons to SCALE would be indicative of differences in WFD approach and not differences in student distributions. In particular, this distribution is 65% BS, 28% MS, and 7% PhD candidates, which is comparable to the 2023 SMART Scholarship program with the exception that the percentage of PhD candidates is smaller.

VI. Pareto Frontier Comparison of WFD Approaches

Pareto frontiers are useful for finding optimal solutions and trade-offs. They are found in n-dimensional *criterion spaces* where each axis is a non-negative goodness measure. Axes conform to one of two frameworks:

- ***Maximization Framework:*** For each goodness measure (each axis), a larger value is favorable. Solutions farther from the origin are better.
- ***Minimization Framework:*** For each goodness measure (each axis), a smaller value is favorable. Solutions closer to the origin are better.

Pareto frontiers allow us to find optimal solutions without having to define a cost or objective function. Using the maximization framework, two solutions A and B can be compared based on each goodness measure or axis coordinate. If solution A has larger axis coordinates (goodness measures) for every axis than solution B, then clearly A is more optimal than B. *It is then said that A dominates B*. The collection of solutions which cannot be dominated by any other solution can be plotted to reveal a frontier of optimal solutions, which then inform *tradeoffs within the criterion or solution space*.

Two different two-dimensional criterion spaces conforming to the maximization framework are described below. They utilize metrics in the KPI scorecard of Table 2 and their values for the three WFD approaches described above (SCALE, internship program, SMART Scholarship program). By using different pairs of metrics, different perspectives on the competing approaches are revealed.

TABLE IV. ROI and KPI Calculation for SMART Scholarship Awardees

Parameter	***BS Degree***	***MS Degree***	***PhD Degree***	***Mixed Degrees****
Scholarship Duration [years]	1 to 3	2	4	Various
Internships Completed [-]	1 to 3	0	0	Various
Cost per Student [K$]	70.5 to 211.5	141.0	282.0	140.6
Students per $100K Cost [-]	0.47 to 1.42	0.71	0.35	0.71
Student Development [K$]	23.2 to 70.0	261.8	574.4	142.9
ROI [-]	1.54 to 5.95	4.11	2.82	3.34

*Same degree mix as active SCALE students

The first Pareto frontier is placed students per $100K cost versus ROI (Fig. 1). This criterion space represents the trade-off between student capacity within budget constraints (y-axis) and return on investment to sponsors (x-axis). As such, this plot speaks to the financial needs of the sponsors. The solutions represented by the squares show that SCALE, based on FY23 performance, is a more optimal approach compared to internships and the SMART Scholarship program since it dominates them in this space.

The SMART Scholarship data points in Fig. 1 for selected degrees inform trade-offs in solutions and limitations of this space. The line on this plot represents one-, two-, and three-year scholarships for undergraduates. The point farthest from the origin (optimal) is for a one-year scholarship. It is sufficient to secure the student's employment post-graduation and it has the lowest scholarship cost. An extension of this trend would be to lower the scholarship award so that it is more akin to a signing bonus. Furthermore, the one-year undergraduate scholarship solution dominates the SMART Scholarship solutions for graduate degrees. Depending on the work sector, a program restricted to undergraduates may not meet overall workforce needs. Therefore, it is important that WFD programs have a target distribution of degrees, lest financial pressures predispose WFD leadership toward undergraduates.

The observations above reveal that this criterion space encourages minimizing sponsor investment to maximize capacity and maximize ROI. While this may be economically attractive, it can easily compromise one aspect of WFD mission, which is to develop students. Since that is not accounted for in this framework, we seek an alternative.

To that end, the second Pareto frontier, shown in Fig. 2, is the average development value of placed students versus ROI. This gives insight into the tradeoff between benefit to students and benefit to sponsors. The solutions represented by the squares show that internship programs are less optimal (dominated) by both SCALE and SMART Scholarship programs. However, in this space neither SCALE nor SMART Scholarship are optimal. Rather, they present a tradeoff between higher development for SMART Scholarship vs higher ROI for SCALE.

The SMART Scholarship data points in Fig. 2 for various degree levels provide further insight. Again, the line on this plot represents one-, two-, and three-year scholarships for undergraduates and shows the inherent trade-off between ROI and student development as program duration changes. Note that student development for masters and doctoral candidates is an order of magnitude greater than for undergraduates and can be achieved at competitive ROI levels. Therefore, if only student development and ROI are considered, this would predispose WFD leaders toward MS students since it dominates the mixed degree solutions. Again, a target degree distribution is needed for WFD efforts to ensure it aligns to workforce demands. Finally, considering only the MS and PhD SMART scholarship solution, neither dominates the other. Rather, they present a trade-off of student development vs ROI.

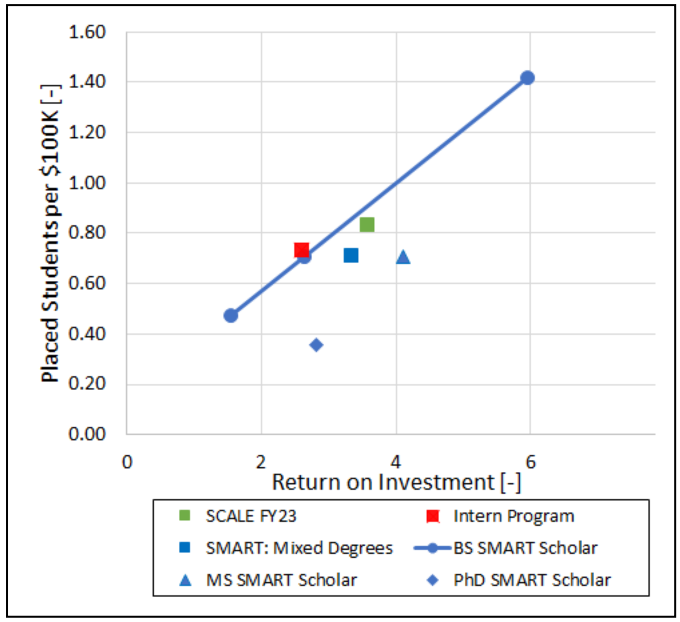

Fig. 1. Placed Students per $100K Cost vs ROI

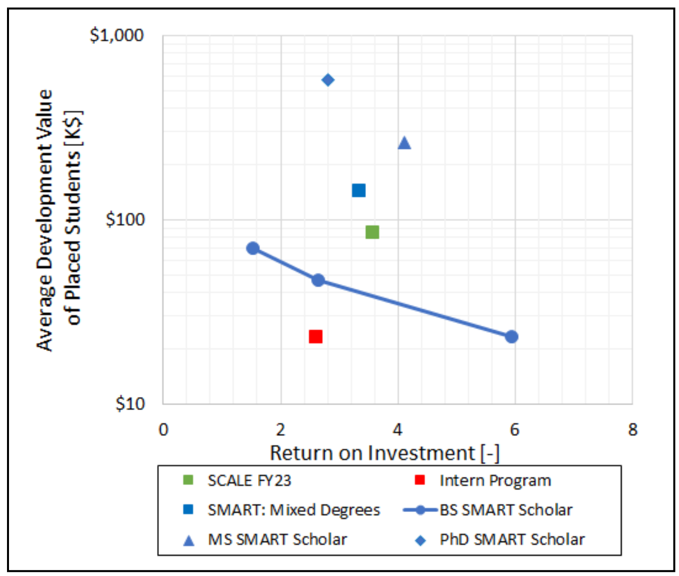

Fig. 2. Average Development Value of Placed Students vs ROI

VII. ROI and KPI Utility For Process Improvement

Simplicity of the ROI metric and associated KPI scorecard enable proforma analyses to predict the impact of process improvements. As mentioned above, at the time of this writing SCALE is in its second year of production. ROI and KPI improvement can be expected over time since program elements are not all in place and student membership will continue to grow. Key findings for SCALE that also illustrate the utility of the ROI and KPI metrics are reported below.

Specific improvements that increase student development value and which SCALE is pursuing include:

Certification: Student technical area certifications will be awarded through a combination of coursework and exams. Assuming a certificate is equivalent to 9 credit hours, and that 75% of placed students have a certification, average development per placed student would increase by $21K once it is implemented.

Security Clearances: Assuming 30% of placed students obtain a security clearance before beginning employment, this would increase average development per placed student by $7K. Currently, only a few percent of students report having obtained a clearance.

Veteran Outreach: Assuming 5% of placed students have 2 to 6 years of applicable military service, and it is credited toward SCALE experience calculations, average development per placed student would increase by $9K to $28K.

Together, these three improvements would raise average development per placed student to $142K (65% increase). ROI would increase to 4.04 (13% increase) while the placed students per $100K is unchanged.

Increasing the number of students, without increasing funding, is possible since students are not guaranteed to receive any direct funding. The number of students at each of 25 different combinations of technical area and university varies from 1 to 104, with an average of 21. Not all SCALE universities are at the same level of maturity and nine have less than 10 students. If each of these university and technical area combinations grew to at least 10 students, the number of active students would increase by 10% from 522 to 575. Corresponding improvements can be expected in number of placements (from 127 to 140), students per $100K cost (from 0.83 to 0.91), and an ROI increase to 4.03 (13% increase).

If all the improvements above were implemented, it would raise ROI to 4.55, which is a 27% increase from FY23 and 36% higher than the SMART Scholarship program, while offering the same development value to students as SMART and an increase in students per $100K of 28% compared to that program.

VIII. CONCLUSIONS

Workforce development investments transform to value when participants are hired in the corresponding industry. Behind every hire in a new or emerging technical area, there are countless hours of curriculum development, new or modified course offerings, co-curricular and mentoring activities, all designed to support the person's obtainment of essential knowledge, skills, and abilities. The ROI number represents in financial terms the benefit of those resource investments. While it does not explicitly quantify the "quality" of the training as do educational evaluation, nevertheless the quality of the person's training drives the hire. Thus, ROI is an outcome metric that complements finer grained process-level metrics to monitor the quality of the programming, akin to health metrics.

Judging which WFD programs are and will be effective at scale is important to support WFD sponsor investment decisions. To that end, novel ROI and KPI metrics for engineering and technician WFD programs have been derived in this work by analogy to established business metrics. The target audience is WFD sponsors and directors. Pre-program estimates based on reasonable assumptions can gain funding commitments, and ongoing application can reveal paths to higher performance.

Simplicity of ROI and KPI formulation minimizes opportunities for gamesmanship, demands of data collection beyond that necessary for basic program administration, and resource commitments that could have been otherwise invested in identifying needed knowledge-skills-abilities (KSAs), developing and delivering curriculum, and evaluating program effectiveness. Application to a leading WFD effort that is focused on microelectronics STEM undergraduate and graduate students (SCALE) has been demonstrated, as has reapplication to alternate WFD development approaches such as internship programs and the SMART Scholarship program.

Two criterion spaces and Pareto frontiers have been used to compare the three WFD approaches mentioned above. The first frontier focuses on sponsor financial considerations and tradeoffs between ROI and capacity within a given budget. This perspective motivates the sponsor to focus preferentially on undergraduates and to minimize financial investment necessary to place the student in the workforce. A limitation of this frontier is that no account is made for the value of student development. The second Pareto frontier reveals a tradeoff between the value of student development and ROI, motivating the sponsor to focus preferentially on masters students. The limitation of this frontier is that no account is made for capacity within budget. Two notable findings result:

- Because of differences in student development value and cost per student across degrees, any WFD program with multiple degree levels needs to have a target distribution of degrees.
- Holistic WFD program evaluation needs to include both Pareto frontiers or a single three-dimensional criterion space based on the three axes of the two frontiers (placed students per $100K cost; ROI; average development value of placed students).

Lastly, the benefit of ROI and KPIs for assessing the impact of process improvements was demonstrated. Proforma analysis was shown to be useful for prioritizing efforts and setting year-over-year targets for ROI and KPIs. These improvements are relevant to numerous WFD programs and show the strong value of implementing student certification and authorization, and in recruiting candidates that bring prior knowledge and experience to the workforce following graduation.

IX. FUTURE WORK

Future work includes partnering with other WFD efforts on ROI and KPI reapplication, thereby advancing the use and refinement of these metrics. As mentioned in the Introduction, several WFD programs exist that could offer opportunities for learning and research. Scope should include initiatives having:

- Community college or technician training
- Sponsorship at the regional, state / province, or local level

This would expand ROI and KPI body of knowledge across a broader range of programs and sponsors.

Moreover, the SCALE program, with 25 different combinations of universities and technical areas, presents a valuable opportunity to uncover best practices and limiting factors affecting ROI and KPI performance, and determine granularity limitations of our approach. This is a logical next step to advance knowledge of ROI and KPIs along with WFD approaches.

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NOMENCLATURE

Symbols:

C: Project costs during the period [$]

Dno_auth: Discounted fraction of value to employer of employees without authorizations [-]

nplaced: Number of students placed during the period [-]

R: Project returns during the period [$]

ROI: Return on investment [-]

SFfield,deg = Average starting salary + fringes for a given field of study and degree [$/year]

Vauth: Value of placed student's authorizations [$]

Vdegree: Value of placed student's academic credentials [$]

Vdev: Value of placed student's development [$]

Vexp: Value of placed student's experience [$]

Vplaced: Value of a placed student [$]

Vtrng: Value of placed student's training [$]

Yapply: Average post-employement time period to obtain an authorization [years]

Yauth: On-the-job experience equivalent of placed student's authorizations [years]

Ybase: Transition period from pre-employment training to post-employment experience [years]

Yexp: On-the-job experience equivalent of placed student's pre-employment work experience [years]

Ytrng: On-the-job experience equivalent of placed student's pre-employment special training [years]

Subscripts:

i: Reference to the i^{th} placed student