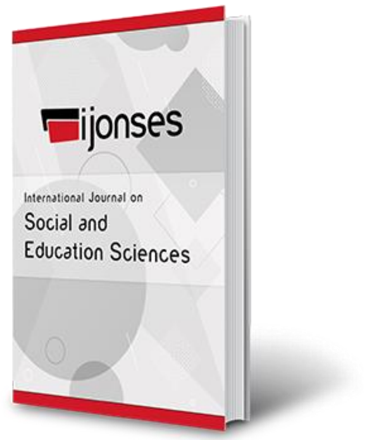

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To cite this article:

McSween, V.K. (2024). An integrative approach to STEM workforce preparation in a biomedical science course [quality improvement]. *International Journal on Social and Education Sciences (IJonSES), 6*(2), 174-187. https://doi.org/10.46328/ijonses.653

International Journal on Social and Education Sciences
2024, Vol. 6, No. 2, 174-187 https://doi.org/10.46328/ijonses.653

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Article Info

Article History

Received:
14 November 2023
Accepted:
24 March 2024

Keywords

Broadening participation
Workforce preparation
Individual development planning
Biomedical science

Abstract

Successful retention of STEM majors that then successfully transition into the U.S. STEM workforce is a major challenge for institutions of higher education. The present work represents a quality improvement study of a custom-designed professional development course for undergraduate students characterized by an innovative integration of workforce preparation activities into a STEM content knowledge course. The QI study investigated the student-perceived impact of participation in goal setting and skill assessment utilizing an individual development plan and whether participation in the custom-designed training course increased student proficiency in STEM workforce-relevant skills. Program evaluation data was used to address the professional development needs of undergraduate STEM students, who are members of underrepresented groups in biomedical science. Evaluation data was used to design the professional development course to target and customize structures to support student success planning and goal attainment. Analysis of reported outcomes indicates that most students benefited from participation in the course and experienced a positive impact on their proficiency in workforce relevant skills and goal setting. This integrated approach to workforce preparation in STEM may address some of the persistence and retention challenges that threaten the size and diversity of the future STEM workforce within the U.S.

Introduction

Successful retention of STEM majors that then successfully transition into the U.S. STEM workforce is a major challenge for institutions of higher education (Whalen & Shelly, 2010; Chen, 2013). These unsuccessful transitions may result in STEM talent shortages that threaten the growth and stability of the U.S. STEM workforce (NSF, 2010; Olson & Riordan, 2012). STEM attrition may be influenced by several factors including inadequate academic advising and career counseling, lack of appropriate institutional support, lack of role models and mentoring, as well as several other psychosocial factors (Chen, 2013). One approach to addressing barriers to STEM workforce sustainability is STEM- focused career interventions (Feller, 2011; Byars-Winston, 2014; Ainslie & Huffman, 2019; Waite & McDonald, 2019). Interventions may take a variety of forms, including but not limited to summer bridge programs (Johnson, 2016; Kitchen et al., 2018), undergraduate research opportunities and mentoring (Salto et al., 2014; Carpi et al., 2017; Estrada et al., 2018; Atkins et al., 2020), psychosocial interventions (Falco & Summers, 2019; Kricorian et al., 2020; Estrada et al., 2018), and career planning courses (Winters et al., 2018; Liu et al., 2022; Kelp et al., 2023) to promote student interest and access to STEM careers.

Academically oriented tools can be used to assist minoritized students in navigating STEM career pathways and opportunities. One academically oriented tool is the Individual Development Plan (IDP), a professional tool that identifies objectives or goals that a mentee and their respective mentor have identified as critical to the student's academic and professional development (Branchaw, 2020). It serves as a self- tracking tool to facilitate a starting point for communication and alignment of expectations between two professionals (Branchaw, 2020). This career planning tool serves as an effective intervention to promote career readiness and enhanced workforce preparedness. STEM- focused career planning interventions and measures of career readiness are significant predictors of STEM student retention (Belser et al., 2017, 2018b). STEM- focused career planning activities are also found to reduce negative career thoughts in STEM undergraduates (Belser et al., 2018a). IDPs promote mentoring interaction and support which enhances career- related outcomes in STEM students (Chang et al., 2021). Furthermore, IDP use reduces identity- related anxiety and increases self- efficacy, learner agency and goal attainment, as well as successful transition into PhD programs (Hardy et al., 2021) and supports development of non-cognitive skills associated with academic success (Aryee, 2017). STEM- career planning and counseling should be strategically included in STEM education programs due to their positive impact on STEM student retention (Belser et al., 2018b).

This work represents a quality improvement study of a custom- designed professional development course for undergraduate students interested in careers in biomedical science or related fields. It provides a programmatic description of the Certificate Program in Biomedical Laboratory Science, along with a custom- designed professional development course for integration into the Certificate. The present work describes the utilization of program evaluation data to address the professional development needs of undergraduate STEM students, who are members of underrepresented groups in biomedical science. The design of the course utilizes targeting and customization of structures to support student success planning and goal attainment. The proposed curricular design of the professional development course aims to provide training and skill development to learners that enhances their preparation for advanced degree programs in STEM & the STEM workforce. We address the following questions: What is the student- perceived impact of participation in goal setting and skill assessment, utilizing an individual development plan? Did participation in the custom- designed training course increase student proficiency in STEM workforce- relevant skills? What recommendations do students have for improvements in future iterations of the course?

Background

The University of the Virgin Islands is a public, land- grant Historically Black College and University (HBCU) and is the only institution of higher education within the U.S. Virgin Islands. The University received funding from the Department of Education Title III Part F- Strengthening HBCU Program under the Fostering Undergraduate Talent by Unlocking Resources for Education (FUTURE) Act to develop a Certificate in

Biomedical Laboratory Science at the institution. The main project serves to increase the number of underrepresented minorities that enter the biomedical workforce, and support development of the healthcare workforce within the U.S. Virgin Islands. Goals of the project include: "To provide students with the knowledge and skills that are necessary for a career in the biomedical sciences" and "To increase the biomedical research capacity at UVI". The paradigm of the Certificate Program is a 2- year sequence; however, it can be completed in 1-2 years, based on student preparation. In year 1 of the curriculum, students take general biology, chemistry, and data science courses. In year 2, students take Methods in Biomedical Science I, Methods in Biomedical Science II, and Professional Practice in Biomedical Science. Year 2 courses were specifically designed for incorporation into the new certificate program. Professional Practice in Biomedical Science is an asynchronous, online 1- credit course that introduces learners to practices that support the general operation of a clinical laboratory and the necessary skills to be a competent biomedical scientist. Course content focuses on laboratory organization, laboratory safety, method validation, quality control procedures, regulatory requirements, and continued learning. The official course description states, "This course will focus on a set of values and conforming to a code of conduct while performing the essential duties of a biomedical scientist." The original course idea emphasized content knowledge around laboratory equipment and processes.

In collaboration with the Mentoring and Research Infrastructure Component of the Virgin Islands Institute for STEM Education Research and Practice (VI- ISERP) the original course was redesigned to include a professional development component that focused on career planning, skill assessment, and skill development. VI- ISERP is a research and training center "dedicated to developing and implementing research-based best practices in teacher preparation and training, student learning, and workforce development in STEM fields through collaboration among university faculty, K-12 educators, government agencies and industry" (VI- EPSCoR, n.d.). VI- ISERP is the education and workforce development component of the Virgin Islands Established Program to Stimulate Competitive Research (EPSCoR), an R-II Track-1 grant, funded by the National Science Foundation (NSF, n.d.). The grant, "Ridge to Reef Processes and Interdependent Drivers of Small Island Resilience" focuses on the "development of the U.S. Virgin Island's scientific capacity and its ability to support economic growth" and increasing "the quality and volume of nationally competitive research and grow a STEM-educated workforce to meet the challenges facing our islands" (Virgin Islands Established Program to Stimulate Competitive Research, n.d.).

The course emphasizes career readiness and skill development which is aligned to the mission of the UVI College of Science and Mathematics. The academic unit "is committed to helping students excel academically and achieve productive careers through programs in academics, research, and community service. Our academic programs emphasize critical thinking, problem solving, written and spoken communication and other skills tailored to help the students succeed. College faculty are committed to lifelong learning and scientific research, academic and pedagogical advancement, and outreach to the local community through service and enhanced opportunities" (University of the Virgin Islands College of Science and Mathematics, n.d.).

In Fall 2022, a training workshop on "STEM Career Planning: A Guide to Successfully Entering the STEM Workforce" was conducted by VI- ISERP. Workshop participants, characterized by being primarily senior and junior undergraduate students in STEM or psychology, were asked to evaluate what factors impacted their career planning choices when selecting a graduate school, professional school, or a job. The activity was adapted from Entering Research: A Curriculum to Support Undergraduate and Graduate Research Trainees produced by the Center for the Improvement of Mentored Experiences in Research (CIMER) at the Wisconsin Center for Education Research at the University of Wisconsin Madison. It is an evidence-based active learning curriculum for research trainees to promote skill development in several key areas, including professional and career development skills (Branchaw et al., 2019). Collectively, students noted that alignment of their personal goals with the offerings/ opportunities of an institution was of greatest importance to them. Other factors that impacted their career planning choices from more to less important included, but were not limited to funding; coursework requirements and/or professional development opportunities; opportunity to work with a specific advisor, mentor, physician, or teacher; feeling of inclusivity- seeing that there are others like you there; relative value of teaching and research training; and happiness of other graduate/ medical students/ coworkers in the program. This provided a better picture of what potential workshops could be offered to students to assist them in making effective career planning choices, for example, workshops on goal setting, how to find funding sources for graduate or professional schools, professional development workshops, and psychosocial interventions that promote a sense of belonging in STEM spaces or build STEM identity or self- efficacy in students.

Also in Fall 2022, students in Methods in Biomedical Science I were asked to complete a needs assessment related to their self- reported proficiency in STEM workforce- relevant skills. Students utilized myIDP, the web- based career planning tool, hosted by the American Association for the Advancement of Science (AAAS), Science, Federation of American Societies for Experimental Biology (FASEB) along with other partnering institutions. The tool utilizes skill assessment and goal setting via an individual development plan framework to assist students with self- reflection around planning their academic, research, training, and career activities (AAAS, n.d.). These assessment areas included: scientific knowledge, research skills, communication, professionalism, management and leadership skills, responsible conduct of research, and career planning. The assessment revealed that students reported the lowest proficiency in several areas related to scientific knowledge, research skills, communication, professionalism, management and leadership skills, responsible conduct of research and career planning (see Table 1). The deficiency score denotes the percentage of respondents that indicated moderate or high deficiency in the respective skill (only the skills for which 25% or more respondents indicated moderate or high deficiency were noted).

These assessment data were strategically used to address the professional development needs of undergraduate students by custom- designing the professional development course to address some of these potential target areas for STEM student skill development.

Course activities in the content knowledge track were geared toward building knowledge and understanding of effective laboratory practice and management, while activities in the professional development track were geared toward facilitating student entry into advanced training programs or the STEM workforce. Learning objectives were utilized for both the content knowledge and professional development tracks within the course (see Table 2).

Throughout the 16- week semester students were asked to utilize their myIDP accounts to participate in career planning activities. Students were required to update or start their individual development plans at the beginning of the semester, assess their current proficiency in several STEM workforce- relevant skills, monitor the progress of their goal attainment, track their professional development activities throughout the semester, and at the end of the semester reassess their skill proficiency in STEM workforce- relevant skills. As part of the professional development course, students were required to attend at least 3 professional development activities throughout the semester that would contribute to their growth in entering a biomedical science or a related science field. Course instructors posted additional opportunities on the course Blackboard site; however, students were free to select and suggest other activities for themselves and their peers to participate in (seminars, workshops, conferences, etc.).

Table 1. Potential Target Areas for STEM Student Skill Development

ASSESSMENT AREAS	Deficiency Score
Scientific Knowledge	
Deep knowledge of my specific research area	**28.6**
Critical evaluation of scientific literature	**26.7**
Research Skills	
Technical skills related to my specific research area	**26.6**
Experimental design	**26.6**
Statistical analysis	**40**
Navigating the peer review process	**33.3**
Communication	
Writing scientific publications	**40**
Writing grant proposals	**86.7**
Training and mentoring individuals	**26.6**
Professionalism	
Contributing to institution (e.g. participate on committees)	**26.7**
Management and Leadership Skills	
Developing/managing budgets	**28.5**
Responsible Conduct of Research	
Demonstrating responsible authorship and publication practices	**26.6**
Career Planning	
How to interview	**26.7**
How to negotiate	**33.3**

Table 2. Course Schedule with Weekly Content Knowledge and Professional Development Tracks, along with associated Learning Objectives.

Week #	Content Knowledge Track	Professional Development Track
1	*n/a*	**SMART Goals & Goal Setting** LO: Generate and implement SMART goals for the academic, professional, and personal areas of your life
2	**Laboratory Safety** LO: Discuss the importance of awareness and practice of laboratory safety in the biomedical lab	**Skills Assessment & Feedback & SWOT Analysis** LO: Self- evaluate your workforce- relevant skills and assess your current strengths and weaknesses
3	**Risk Management** LO: Discuss best practices for risk management in the biomedical lab	**Diversity, Equity, and Inclusion** LO: Reflect on the value or benefits that diversity, equity, inclusion brings to the biomedical workforce
4	**Bio-safety Control Measures & Bio-safety Levels** LO: Discuss the importance of biosafety control measures and biosafety levels in mitigating biological risk in the biomedical lab	**Career Exploration: Career Research Log** LO: Research several STEM- related careers that may be potential workforce pathways based on your current skills, interests, or values
5	**Chemical/ Biological Waste Management** LO: Discuss the management of waste products and principles of decontamination practiced in the biomedical lab	**Career Exploration: Informational Interview** LO: Interview a STEM professional in a STEM career to investigate more about the profession and skills needed to be successful in that career
6	**HIPAA and Patient Safety** LO: Discuss the importance and practice of keeping patient health information safe.	**Advanced Training or Workforce Pathways** LO: Research and log the characteristics of potential workforce positions or graduate/ professional/ medical school programs that align with your interests
7	**Protection of Human Subjects in Research** LO: Discuss how ethical principles help resolve conflicts or “gray areas” when conducting research with human subjects	**Resume/ CV Building** LO: Generate a professional resume or curriculum vitae that can be utilized for applications to STEM training programs or workforce positions
8	**Use of Animals in Research** LO: Discuss how the 3R’s are used to manage the use of animals in scientific	**Mock Interview** LO: Engage a faculty member or mentor to interview you and assess your interview skills and

Week #	Content Knowledge Track	Professional Development Track
	research	professionalism
10	**CLIA & Quality Laboratory Management** LO: Discuss how CLIA guidelines are used to promote quality laboratory testing in clinical labs	**Mentoring & Support Networks** LO: Build an effective mentoring team to support you in implementation of your SMART goals and individual development plans
11	**Research Design** LO: Discuss how to apply appropriate research design to biomedical research projects	**Scientific Reading** LO: Critically evaluate a peer- reviewed scientific research article in your area of interest
12	**Data Management** LO: Discuss and apply FAIR principles for data management of biomedical data	**Scientific Writing** LO: Critically evaluate an abstract and rewrite the abstract to promote more effective understanding of the scientific study
14	**Data Analysis & Interpretation** LO: Discuss the application of statistical tests to biomedical data to derive meaning	**Science Communication** LO: Communicate science effectively to several different target audiences
15	**Method Validation** LO: Discuss strategies for ensuring reliability of analytical methods in a biomedical lab	**Addressing Conflict** LO: Identify and implement strategies for more effective conflict resolution

Method

Evaluation Approach

During week 14 of the course, students completed a program evaluation questionnaire on the self- reported impact of the professional development course on multiple outcomes. After the close of the semester, course instructors de-identified and collated all student responses for the respective prompts. Student responses were qualitatively summarized for presentation in the current article. As part of the feedback questionnaire, students were asked to rank content knowledge topics and professional development activities based on what they perceived the relative value to be. Additionally, students participated in self- assessment of their workforce- relevant skills utilizing their individual development plans. Their initial assessment at the beginning of the course (week 1) was compared to their final reassessment at the end of the course (week 16) to identify whether students reported any self- perceived changes in proficiency levels.

Data Analysis

Student rankings were collated and the median and mode was identified for each content knowledge topic and professional development activity. Topics were ranked utilizing the median value for each topic for both the content knowledge topic and professional development activities. Student- perceived value of the topics was assessed by calculating the median rank for each topic. Topics that ranked between 1-5 (highest value), 6-10 (intermediate value), 10+ (least value). The non- parametric Sign Test was utilized to compare the medians of the pre and post self- assessment responses in student individual development plans.

Table 3. Median and Mode Values of Student Ranking for Professional Development and Content Knowledge Topics

Professional Development	**Median**	**Mode**
Skills Assessment & Feedback & SWOT Analysis	3	3
Mentoring and Support Networks: Building your Mentoring Team	3	2
Advanced Training or Workforce Pathways	3.5	3
SMART Goals + Goal Setting	4.5	1
Career Exploration: Career Research Log	4.5	4
Career Exploration: Informational Interview	5.5	10
Resume/ CV Building	6	7
Mock Interview & Feedback	6	1
Diversity, Equity and Inclusion	8	9
Scientific Reading	8	10
Scientific Writing	8	5
Science Communication	8	N/A
Addressing Conflict	12	12

Content Knowledge	**Median**	**Mode**
Laboratory Safety	3.5	1
HIPAA and Patient Safety	3.5	1
Protection of Human Subjects in Research	3.5	2
Biosafety Control Measures & Biosafety Levels	4	4
Risk Management	4.5	7
Use of Animals in Research	5.5	2
CLIA & Quality Laboratory Management	6	8
Research Design	6	7
Data Management	6.5	4
Data Analysis & Interpretation	7	N/A
Chemical/ Biological Waste Management	8	9
Method Validation	8	N/A

Results

Quantitative evaluation of matched pre and post IDP assessments (n= 9) revealed that 66.67% or ⅔ of learners demonstrated a change in their self- reported overall proficiency level in the assessed skills ($p < .05$). A more targeted analysis of individual skills indicated that impacted skills included “Broad based knowledge of science” ($p=.014$), “Technical skills related to my specific research area” ($p=.045$), “Statistical analysis” ($p=.045$)”, “Speaking clearly and effectively” ($p=.045$), and “Contributing to discipline” ($p=.045$).

The most valuable professional development activities for students included: Skills Assessment & Feedback & SWOT Analysis; Mentoring and Support Networks: Building your Mentoring Team; Advanced Training or Workforce Pathways; SMART Goals + Goal Setting; and Career Exploration: Career Research Log. Similarly, the most valuable content knowledge topics for students included: Laboratory Safety; HIPAA and Patient Safety; Protection of Human Subjects in Research; Biosafety Control Measures & Biosafety Levels; and Risk Management (see Table 3).

Student suggestions for additional professional development topics included time management, how to write a personal statement and cover letter, as well as how to write grants and research proposals. In contrast, student suggestions for additional content knowledge topics included biomedical informatics, imaging, stem cell research and conflict of interest in research, and integration of activities such as online laboratory exercises, clinical case studies, synchronous discussions, and in- person meetings.

Qualitative responses to the feedback questionnaire indicated that most students benefited from participation in the course. Only a small subset (16.7%) of students had previously participated in an in-depth assessment of their skills and competencies. One respondent noted, “No, I didn’t even know it was a thing”, while another stated that “prior to this course, I have not dedicated a lot of time to doing this, so I am glad to have done this in the course, so I know what to work on before I graduate to make me a stronger applicant”. Respondents also noted that the course provided a better understanding of career development and career opportunities, “I struggled with trying to narrow down my interests regarding my career path and/or end goals but the assignments given allowed me to spend more time finalizing my path after graduating” and “allowed me to progress towards the next academic stage by providing me an abundance of knowledge about biomedical science and the variety of avenues that are present within such a career field”. Respondents highlighted specific activities that they found valuable toward their growth, for example, “...it was helpful to have the interview with a professional in a field of interest because I was able to ask some of my questions about what it is like to be a physician. I also think that having to make a draft of our CV was helpful because I ended up having to use it for summer applications a couple weeks later”, in addition to, “The different weekly readings enhanced my knowledge of biomedical science and research. What I liked the most, however, was gaining knowledge by looking at ideas through the perspective of my peers. During several discussions, points were made that I personally would not have considered”.

Most students (66.7%) noted that building their mentoring team helped them to reflect on the value of mentorship in helping them achieve their personal, academic, and professional goals. However, a subset of students (33.3 %) noted that they did not successfully build their mentoring team but will do so in the future due to the perceived value of such a network ($n= 12$).

91.7% of respondents agreed that they found individual development planning beneficial and would recommend goal setting and self- assessments of skills, interests, and values to their peers (n= 12). 75% of respondents indicated they intended to utilize their IDP after completion of the course, while 8% were unsure, 8% would not, and 8% indicated they would utilize another means to facilitate their goal setting (n= 12). In contrast, 41.7% of the same respondents indicated they intended to utilize their IDP after graduation, while 25% were unsure, 16.7% would not, and 16.7% indicated they would utilize another means to facilitate their goal setting (n= 12).

64% of respondents noted that participation in IDP planning increased their interest in joining the STEM workforce, while another 36% students noted that it did not affect their interest; however, this was because of their strong interest in STEM careers prior to participation in the course (n= 11). For some students, there were additional impacts on their self- efficacy. For example, one respondent noted that, “Participating in building/implementing a personalized Individual Development Plan helped me become more confident in my skills… I rated myself low in several different skill categories. However, when my mentors rated me, their scores were higher which helped boost my self-confidence”, similarly another learner commented that “It was a constant reminder of what I had to do to get to the next step and encouraged me at times when I was feeling overwhelmed. Being able to see the goals written down was motivating.”

100% of percent of students noted that they benefited from assessing their skills within the different domains (n= 10). Benefits included more effective prioritization of focus areas for short versus long term goal planning; a new focus on the development of non- cognitive skills, such as communication and professionalism; identification of the relevant skills sets needed to be successful in their career of interest; additionally, identification of their relevant strengths and weaknesses.

Discussion

The present quality improvement study demonstrates the utility of program evaluation data to address the professional development needs of undergraduate STEM students and the effectiveness of integration of workforce development and career readiness activities into a STEM content knowledge course. Participation in the course increased or further supported student interest in joining the STEM workforce or participation in STEM research. Effective implementation of career- planning courses positively impact student goal setting and increases work-force entry after graduation (Winters et al., 2018), as well as facilitates increased awareness (Freeman, 2012; Layton et al., 2020) and self- confidence toward career preparation (Freeman, 2012). Skills that were positively impacted by the integrated course intervention included workforce- relevant skills in the areas of Scientific Knowledge, Research Skills, Communication, and Professionalism. Two thirds of students demonstrated statistically significant changes in their self- reported proficiency levels in workforce- relevant skills in several key areas. McGunagle & Zizka (2020) recommends that educational institutions with STEM training programs conduct a reassessment of current curricula to reduce the disparity between student competencies and the practical needs of the STEM workplace. Results confirm that students found both the traditional STEM content knowledge and career readiness experiences relevant and valuable to their overall training experiences as future STEM professionals. Qualitative student feedback further supported these findings, as one respondent noted, “I love this course because it opens you up to many opportunities". Effective use of IDPs has the potential to positively impact career development (Vanderford et al., 2018) of learners, as well as facilitate effective mentoring opportunities and enhance their career- related outcomes (Chang et al., 2021).

Student recommendations for alternative course content in both the STEM content knowledge and professional development tracks will be further reviewed to improve the design of the integrated course and amplify its impact on student outcomes, such as STEM self- efficacy and STEM career interest. Future work may investigate the longitudinal impact of the course on additional psychosocial factors that increase student retention in STEM majors and careers. Psychosocial factors, such as self- efficacy, sense of belonging, theories of intelligence and grit, have been associated with successful undergraduate STEM student engagement and retention (Lytle, De Rosa, & Fisher, 2021). Faculty recommendations include increasing opportunities for students to receive feedback on their individual development plans from both course instructors and mentors, as well further diversifying the assignment type in the content knowledge track to increase student engagement in the online course.

Conclusion

This model of using data- driven evaluation of student training needs to inform the redesign of a STEM course that emphasizes workforce preparation and career readiness can be easily translated to other STEM courses, or even scaled- up to become a core component of STEM offerings within a department. This approach may positively impact student persistence and retention within their STEM major and increase the likelihood of student entry and retention into advanced training programs in STEM or directly into the STEM workforce, particularly for students from groups that have been historically underrepresented in STEM.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1946412 and the U.S. Department of Education Title III Part F - Strengthening HBCU Program under the Fostering Undergraduate Talent by Unlocking Resources for Education (FUTURE) Act Program.

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