Features of a STEM Leadership Program

This report presents key findings from surveying and interviewing STEM education stakeholders in Washington State in order to describe the key skills, concepts, and performances a STEM Leadership graduate program for grades 5-12 should develop (Project Goal 1). The results of this survey will be used by Central Washington University to design a graduate program for STEM teachers. The report concludes with a literature-based, survey-informed framework for positioning CWU's program as a STEM network hub for advancing STEM education in the state.

September 2020

A project by the Teach STEM Program at Central Washington University with support from the National Science Foundation (DUE #1950332)

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Executive Summary

The goals of the *Building Capacity for a Master Teacher Specialization in STEM Leadership* project were two-fold:

> Goal 1: Survey and interview a large population of STEM education stakeholders in WA state in order to describe the key skills, concepts, and performances a STEM Leadership graduate program for grades 5-12 should require.
>
> Goal 2: Use these data to design curriculum, a recruiting plan, administrative structure, and formalized partnerships with high-need schools for a novel specialization in STEM Leadership for Central Washington University's existing graduate level Curriculum and Instruction program.

This report summarizes results related to addressing Goal 1 and provides implications for addressing Goal 2. Project work related to Goal 2 is presented in a separate report, *STEM Leadership Program Curriculum and Organization*.

The project leadership team investigated three key considerations when designing a STEM Leadership program to serve K-12 STEM education in Washington State:

RQ1. *What are principles and practices that advance STEM education and that a STEM Leadership program can support?*

RQ2. *Who is the target audience for a STEM Leadership program?*

RQ3. *What are the skills, certifications, and responsibilities necessary for an effective STEM leader, thus establishing guidelines for program curriculum?*

Utilizing a mixed-methods approach, 290 STEM stakeholders were surveyed from four key groups: administrators, STEM support specialists, STEM teachers, and other STEM community and industry partners. Follow-up emails and phone interviews were conducted with 7 of the survey participants, with an additional 4 survey participants taking part in a focus group.

Principles and Practices for Advancing STEM Education

For all stakeholders, the two most important principles/practices for advancing STEM education were integrating STEM projects into all STEM courses and hiring effective math and science teachers. However, STEM teachers feel they need patience and support (such as funding and professional development) to design and implement STEM projects, but are given little time and incentive to participate in professional development activities. Any program supporting the advancement of STEM education must have integrated, project-based learning at its center, as well as the necessary resources to meaningfully integrate community and industry partners.

Who Benefits from a STEM Leadership Program?

All categories of STEM stakeholders indicated it was at least moderately important that all teachers have knowledge and experiences in STEM teaching principles and practices, but that this knowledge and experience was essential for Science, Mathematics, and Computer Science teachers, the target population for a STEM Leadership program. In follow-up interviews, STEM stakeholders revealed that more opportunities to network and collaborate across disciplines and grade levels are necessary. From opportunities to co-teach with STEM teachers in other disciplines, to meaningful professional development, there is a need for infrastructure intentionally structured to promote the collaborative advancement of STEM education.

What Skills, Certifications, and Responsibilities are Necessary for an Effective STEM Leader?

A strong consensus emerged regarding the importance of a STEM leader's ability to *integrate and implement a project-based curriculum*. The other highly rated skill across all groups is the ability to *work collaboratively with colleagues to intertwine disciplines*. Follow-up questions revealed that STEM stakeholders felt these skills are best learned through networking and collaborating with other STEM educators in a supportive environment of like-minded STEM educators. Respondents across all subgroups found certification in Career and Technical Education (CTE) and National Board Certification (NBC) less important for a STEM leader than the particular skills that were surveyed.

The most highly valued STEM leader responsibility was the responsibility of *utilizing culturally responsive teaching practices* to address an essential need to promote diversity and equity in STEM education. While administrators, STEM support specialists, and community and industry partners felt initiating and administrating community-based STEM projects was an important responsibility of STEM leaders, teachers did not feel as strongly that this responsibility was important. STEM stakeholders felt that support from their district and the greater network of STEM educators is essential to supporting STEM leaders to not only use STEM projects but become STEM champions of district and community-wide projects.

A substantial number of surveyed STEM teachers have not had opportunities to design, teach, or participate in STEM projects. Many of these STEM teachers already have a Master's degree, so would not be interested in enrolling full time in our STEM leadership program.

Putting it Together: Supporting a Washington STEM Network with STEM Leaders at the Center

The leadership team curated findings into an overarching framework (see Fig. 1) that represents our vision for the central role a STEM Leadership program can play in advancing STEM education. Central Washington University's STEM Leadership program can serve two equally important roles: (1) improving the effectiveness of STEM teachers by cultivating STEM leaders proficient with research-based and stakeholder recognized pedagogical principles and practices; and (2) connecting STEM stakeholders across Washington State by organizing the program to serve as a regional STEM network hub. Three key pedagogical implications are: curriculum must be centered around project-based units that are integrated across disciplines, teaching must be culturally responsive, and assessment must be authentic.

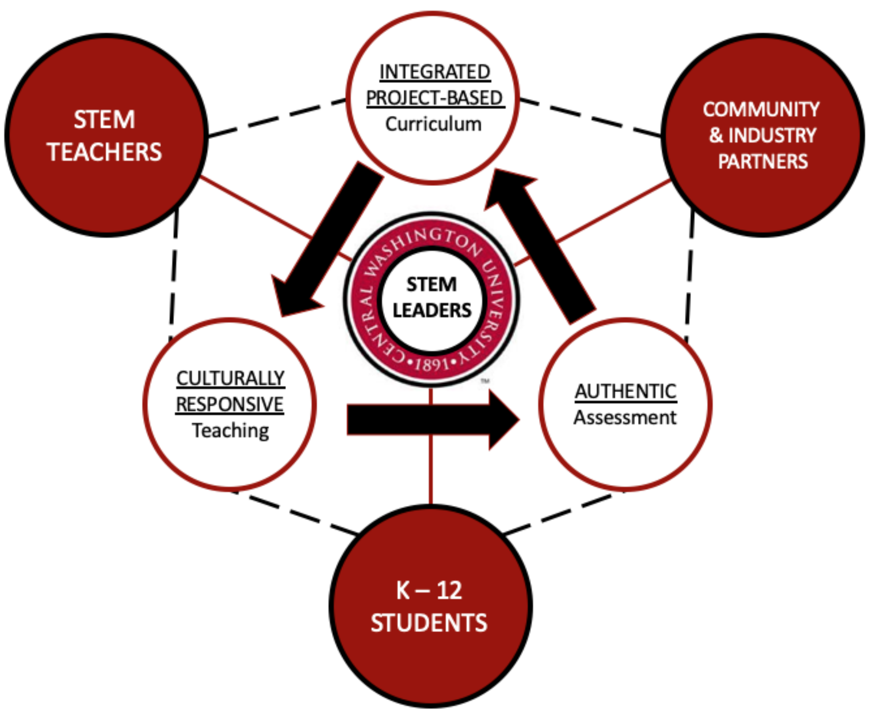

Figure 1. STEM leadership framework informing CWU program design

Three key organizational implications for program design are: for CWU's STEM leadership program to truly serve as a network hub, our program design must intentionally provide a space for all STEM stakeholders, not just those enrolled in the program; National Board certification was not emphasized by survey participants and should not be an explicit curricular focus as was originally planned by the leadership team; careful program design is needed to address logistical concerns to maximize the number of STEM teachers who can participate in the STEM leadership program. These organizational considerations are discussed more explicitly in a separate report, *STEM Leadership Program Curriculum and Organization*.

Methods

Defining STEM. We, the leadership team, recognize that due to its frequent use, "STEM" (and "STEM education") can take on a variety of meanings to a variety of people. For the purposes of this project we take a fairly broad and inclusive meaning, and define STEM as both the component disciplines of science, technology, engineering, and mathematics, as well as efforts to integrate two or more of these disciplines together. Further, in considering STEM education we are mindful of best practices from each of the component disciplines, as well as best practices that are common across all disciplines such as collaboration, use of real-world problems, project-based learning, and creating equitable opportunities for all learners.

Research Questions. The following research questions guided the first phase of this project in order to determine what attributes would be valued in a STEM teacher leader, and what program components they view as likely to develop these attributes:

RQ 1. *What are principles and practices that advance STEM education and that a STEM Leadership program can support?*
RQ 2. *Who is the target audience for a STEM Leadership program?*
RQ 3. *What are the skills, certifications, and responsibilities necessary for an effective STEM leader, thus establishing guidelines for program curriculum?*

Research Design. A mixed-methods approach was utilized to address these questions, with qualitative data supporting quantitative results. We first administered an online survey and then conducted follow-up phone interviews, email interviews, and one focus group with a subset of survey respondents.

Survey Design. The survey was designed collaboratively and based on literature supporting the following characteristics of a STEM teacher leader:

1. STEM teacher leaders model best practices (Aspen Institute, 2014) that promote STEM literacy for all students; increase diversity, equity, and inclusion in STEM; and prepare the STEM workforce for the future (NSTC, 2018). They work to provide a strong STEM education that "is culturally responsive, employs problem- and inquiry-based approaches, and engages students in hands-on activities that offer opportunities to interact with STEM professionals" (Tanenbaum, 2016, p. 1).

2. STEM teacher leaders mentor other teachers in best practices, which requires "significant professional development on leadership" (Aspen Institute, 2014, p.4).
3. STEM teacher leaders engage with a full range of stakeholders in their school districts, communities, and in industry to provide pedagogical support and/or funding for more authentic and equitable student learning experiences (Sublette, 2013; Tanenbaum, 2016).

A summary of survey questions is provided in the Table 2 below, with an 'X' indicating which group of survey participants answered a particular question. Question one was a ranking of five principles and practices identified from the aforementioned literature. Questions two, three, and four were Likert-scale questions assigning to various STEM education attributes three levels of importance: *extremely important*, *moderately important*, and *not at all important*. The skills and responsibilities included in these survey questions were based on the characteristics of effective STEM leaders identified in the literature. Question five was a set of yes/no responses designed to identify teachers' current skills and certifications.

	Administration	**STEM Support Specialists**	**STEM Teachers**	**STEM Partners**
Q1: Rank principles and practices for advancing STEM (RQ1)	X	X	X	X
Q2: Indicate level of importance for various educators to know these principles and practices (RQ2)	X	X		X
Q3: Identify important skills and certifications for effective STEM leaders (RQ3)	X	X	X	X
Q4: Identify important responsibilities of effective STEM leaders (RQ3)	X	X	X	X
Q5: Indicate current skills and certifications (RQ3)			X	
Additional questions regarding program preferences (e.g.,			STEM teachers interested in	

instructional delivery methods)[1]			attending a STEM Leadership program	
Opportunity to share additional thoughts (open-ended)	X	X	X	X

Table 2. Summary of survey questions and which participants answered each question.

Prior to administering the survey, the leadership team incorporated feedback from other STEM education faculty at Central Washington University to establish *face validity* (Gravetter & Forzano, 2012).

Quantitative Data Collection. To answer the research questions from the perspective of STEM stakeholders in Washington State, the leadership team developed and administered the aforementioned survey online via Qualtrics, targeting four categories of key STEM stakeholders:

- Administrators: District Superintendents, School Principals
- STEM Support Specialists: Curriculum and STEM Specialists, Coaches
- STEM Teachers: Classroom math, science, computer science and technology teachers
- STEM Partners: STEM community and industry advisors, Other (e.g., directors of Washington Educational Service Districts)

Stratified convenience sampling was employed to collect survey data. Members of the Apple STEM Network, members of South Central Washington STEM, members of the Washington Science Teachers Association, and graduates of Central Washington University's Teach STEM undergraduate program were contacted until at least 100 responses were received from STEM teachers and at least ten responses were received for each of the three other subgroups of stakeholders.

Between the dates of May 1st and July 1st, 2020, 290 participants completed at least part of the survey. Whenever results are presented in this report, counts are provided to indicate the number of respondents that answered a particular question. Participants' educational positions are summarized in Table 3 below.

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[1] The results of this last set of questions concerning program preferences are provided as part of the *STEM Leadership Program Organization and Curriculum* report.

Educational Position/Role	Count
Administration (District Superintendents, School Principals)	13
STEM Support Specialists (Curriculum and STEM Specialists, Coaches)	18
STEM Teachers (Math, Science, Technology, Computer Science)	208
STEM Partners (STEM community and industry advisors, Other)	51

Table 3. Summary of survey participants' educational positions.

Qualitative Data Collection and Analysis. Qualitative data was collected to supplement and triangulate quantitative results from the survey and consisted of three data sources:

(a) At the end of the survey, participants were given an opportunity to share their thoughts by responding to the following open-ended prompt:

What would you like to tell us about STEM education?
You can explain responses, add new ideas, or ask questions.

(b) Based on thematic analysis of survey results, including this open-ended prompt at the end of the survey, follow-up phone and email interviews were conducted with a subset (n = 7) of survey respondents including representatives from all categories of stakeholders.

(c) Using additional information from the follow-up phone and email interviews, one focus group was organized with four survey respondents including three STEM teachers and one STEM coordinator.

In addition to triangulation of data sources, we used analyst triangulation methods to strengthen the credibility of inquiry (Patton, 2002). In order to develop interview questions for follow-up phone and email interviews, two members of the leadership team independently analyzed survey responses, including the free response question at the end of the survey, identifying repeated themes within and across participant subgroups. The two researchers then met to compare findings and understand any inconsistencies, generating a final list of four themes related to important programmatic aspects and potential barriers to implementation. These themes are introduced in the next section and exemplified in the subsequent results sections.

Themes from Open-Ended Survey Prompt

As mentioned previously, four themes emerged from the qualitative data analysis of the open-ended items on the survey:

1. All stakeholder subgroups mentioned that STEM content needs to be integrated across disciplines.
2. All stakeholder subgroups brought up the importance of promoting equity and diversity in STEM education. Several responses suggested that meaningful community partnerships and PBL might help address equity issues.
3. Teachers felt they are spread thin and there is very limited time to engage in community projects and professional development, especially when they are not given clock hours or some other type of incentive to do so.
4. From a curriculum standpoint, we need rich and engaging activities as well as meaningful applications connecting to industry. However, teachers feel they need support such as funding and professional development to do this.

These themes informed more targeted questions during the subsequent focus group. Questions for the interviews and focus group can be found in Appendix A. These themes, as well as specific quotes, are integrated throughout the results presented and discussed in subsequent sections of this report.

Results: Principles and Practices that Promote STEM Education (RQ 1)

Survey participants were asked:

Question 1: Rank these statements in order of importance for advancing STEM education. (1 = most important and 5 = least important)

Statement A. STEM projects should be integrated into all STEM courses.

Statement B. *STEM education principles are best advanced by hiring effective math and science teachers.*

Statement C. *STEM education should focus on career and technical education (CTE).*

Statement D. *STEM education principles are best advanced through programs with industry and community partners.*

Statement E. *STEM education principles are best advanced through extracurricular programs.*

Table 4 below provides the average rankings of each statement for each stakeholder subgroup of participants. To determine the overall ranking, each stakeholder subgroup was treated as equally weighting the overall ranking. Thus, the ranking provided in each row of the "Average Ranking" column is an (unweighted) average of the four numbers to its right.

Statement	***Overall Ranking***	***Average Ranking (4 subgroups)***	***Administration (13 responses)***	***STEM Support Specialists (14 responses)***	***STEM Teachers (112 responses)***	***STEM Partners* (21 responses)***
A	1	1.89	1.85	1.71	2.14	1.86
B	2	2.14	2.08	1.93	1.91	2.62
C	4	3.32	3.08	3.50	3.37	3.33
D	3	3.15	3.46	3.29	3.13	2.71
E	5	4.51	4.54	4.57	4.46	4.48

Table 4. Summary of average rankings of each statement for each stakeholder subgroup of participants.

Discussion. For all stakeholders, the two most important principles/practices for advancing STEM education were integrating STEM projects into all STEM courses (Statement A) and hiring effective math and science teachers (Statement B). These findings were further triangulated with qualitative results, in which all stakeholder subgroups mentioned that STEM content needs to be integrated across disciplines. In particular, as one STEM coach/coordinator expressed, "The trend and long standing practice of trying to do each one of these [disciplines] exclusive of the other is the biggest hurdle we face." However, effective integration of STEM disciplines can be difficult. Qualitative results revealed that STEM teachers feel they need patience and support to design and implement STEM projects, emphasizing that "support" means funding and professional development to design meaningful curriculum. Unfortunately, STEM teachers also felt they are given little time and incentive to participate in professional development activities, mentioning they are "spread too thin" and that "there is not enough time or space to contain everything." As such, if STEM integration is to happen, teachers must be given the necessary time and support.

Leveraging community and industry partnerships (Statement D) and focusing on career and technical education (CTE) (Statement C) were the second two most important principles/practices for advancing STEM education, with using extracurricular programs (Statement E) being the least important for all stakeholders. Community partners, CTE support, and extracurricular programs help foster and grow STEM learning experiences; however, effectively implemented, integrated STEM projects must be the foundation of STEM education. Any program supporting the advancement of STEM education must have integrated, project-based learning at its center. Accordingly, STEM partners that were surveyed advocated for "integrating community projects, participatory science, and industry partners into the schools."

Results: Who Should Attend a STEM Leadership Program? (RQ 2)

In answering Research Question 1, the research team ascertained the principles and practices stakeholders believed were most important for advancing STEM education. But which STEM educators must have the knowledge and experience with these principles and practices? In other words, which STEM educators could serve as leaders in advancing STEM education and would therefore benefit the most from attending a STEM Leadership program? To answer this question, survey participants were asked the following three-point, Likert-scale question (extremely important, moderately important, not at all important):

Question 2: How important is knowledge and experience with STEM education principles and teaching practices to […] different educators?

Results are presented in Figure 5 in two manners. First, each bar in the following chart shows the percentage of respondents of a particular stakeholder subgroup that selected a particular response. For example, the left-most bar in the chart indicates that roughly 46% of Administrators felt knowledge and experience with STEM education principles and teaching practices was *Extremely Important* for STEM Coordinators.

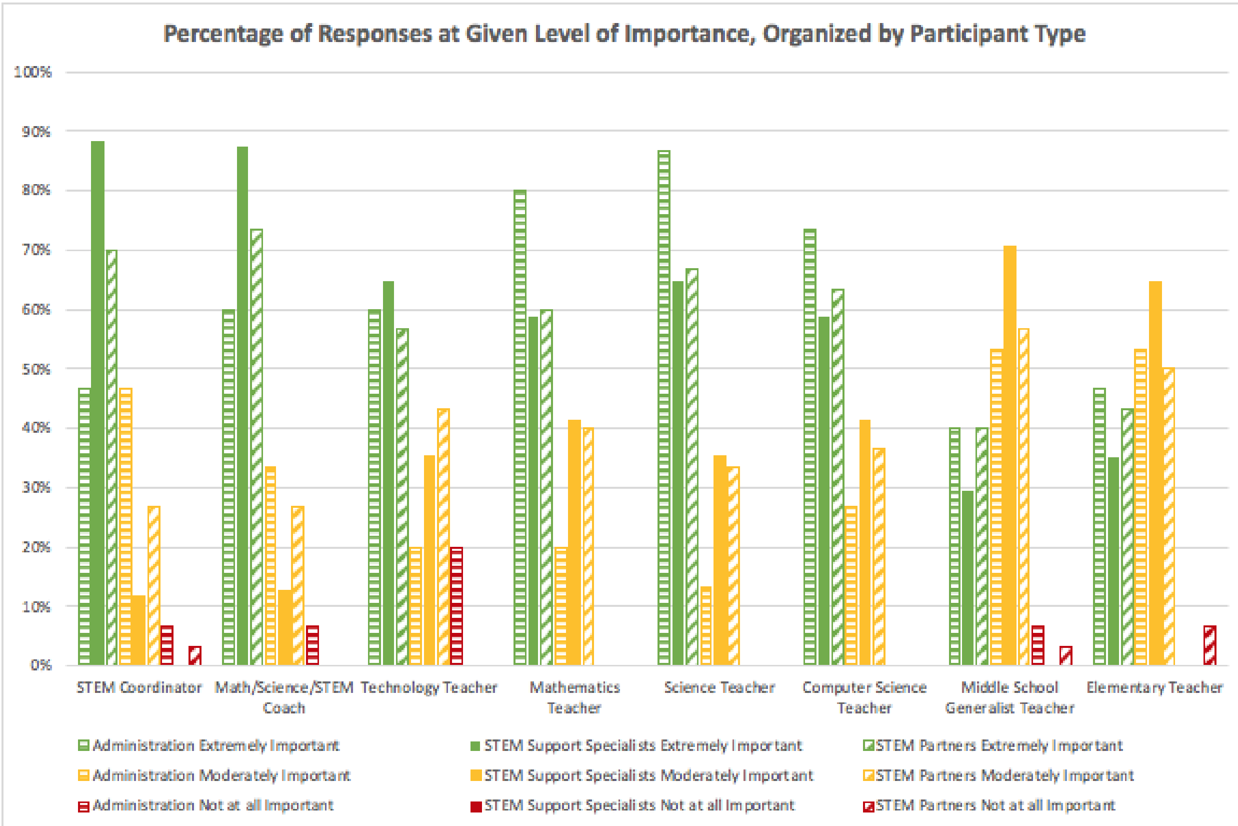

Figure 5. Summary of average rankings of each statement in Question 2 for each stakeholder subgroup of participants.

While the above bar chart separates responses by level of importance (extremely, moderately, not at all), Table 6 provides a one-number, weighted average for the different stakeholder subgroups. Each participant's response was assigned one of the following weights: Extremely Important → 1; Moderately Important → 0.5; Not at all Important → 0. A score close to 0 indicates that, overall, the group of respondents view the respective feature as less important. A score closer to 1 indicates that participants view the respective feature as more important. For example, the 0.94 in the third column of the first row indicates that, overall, the collective group of STEM Support Specialists felt it is highly important for STEM Coordinators to have knowledge and experience with STEM education principles and teaching practices, while the numbers in the penultimate row indicate all subgroups of stakeholders did not feel it was as important for Middle School Generalist Teachers to have this knowledge and experience.

	How important is knowledge and experience with STEM education principles and teaching practices to....		
	Administration (15 responses)	**STEM Support Specialists (17 responses)**	**STEM Partners* (30 responses)**
...STEM Coordinators?	0.70	0.94	0.83
...Math/Science/STEM Coaches?	0.77	0.94	0.87
...Technology Teachers?	0.70	0.82	0.78
...Mathematics Teachers?	0.90	0.79	0.80
...Science Teachers?	0.93	0.82	0.83
...Computer Science Teachers?	0.87	0.79	0.82
...Middle School Generalist Teachers?	0.67	0.65	0.68
...Elementary Teachers?	0.73	0.68	0.68

*Note: STEM Partners were asked the same question with a slight wording change to make the question more relevant to this population of participants. STEM Partners were asked, "When working with a school district on a community or industry STEM project, how important is it to have the involvement of…"

Table 6. Weighted averages for the different stakeholder subgroups addressing Question 2.

Discussion. While stakeholders expressed some variety in the importance they assigned to various groups obtaining STEM expertise, there were some common themes that emerged. For instance, all subgroups surveyed ascribed at least moderate importance for a wide range of educators to have knowledge and experiences in STEM teaching principles and practices. Collectively, as a group respondents indicated that STEM knowledge was less important for some groups of educators, such as middle and elementary teachers, and more important for other groups of educators such as secondary teachers and STEM coaches and coordinators.

However, not all subgroups ranked the relative importance of STEM knowledge for educators in the same way. Administrators tended to rank the importance of STEM knowledge as highest for secondary subject teachers such as math, science and computer science teachers. Administrators ascribed lower, though still moderate, importance to educators holding positions such as STEM coach or coordinator and elementary teachers, with middle school generalist teachers ranking lowest. Conversely, STEM specialists that were surveyed ranked STEM coordinators and coaches as most in need of knowledge of STEM, followed by secondary subject specialists, and middle and elementary teachers as lowest. STEM partners tended to rank the importance of STEM expertise for STEM coaches and coordinators only slightly higher than secondary subject teachers, and slightly lower for middle and elementary school teachers.

In follow-up questions, STEM stakeholders revealed that more opportunities to network and collaborate across disciplines and grade levels are needed. For example, as one high school teacher articulated during a focus group, “In my district, it would be really helpful to be able to co-teach between subjects. For instance, like a math teacher and a science teacher partnering up to co-teach a class, would make that collaboration in STEM easier, rather than just on our preps, coming into a peer’s classroom and observing.” Administrators added that school principals could be particularly effective agents for change when it comes to promoting and advancing STEM education. As one administrator remarked, “Principals need to understand that math, science, technology, engineering, art, and literacy can amplify each other. [...] If administration is in place that emphasizes and encourages teachers to take the risk involved with trying something new in their practice, like teaching STEM projects that incorporate standards from multiple content areas, then we will see change.”

Results: What Skills, Certifications, and Responsibilities are Necessary for an Effective STEM Leader? (RQ 3)

Knowing now which principles and practices are most important for advancing STEM education, as well as which STEM educators should attend a STEM Leadership program geared toward preparing them to lead others in advancing said principles and practices, it remains to understand the specific skills, certifications, and responsibilities necessary for the STEM Leaders to be effective in their change-making efforts. Results are presented in two subsections: Skills and Certifications, and Responsibilities. Similar to the previous section, both bar charts and tables with weighted averages are provided to guide discussion. Finally, at the end of this section we share the current experience, skills, and certifications held by the STEM teachers who responded to the survey. This final question allowed us to determine if a STEM Leadership program might fill an existing gap between the current and ideal levels of STEM teacher experience, skills, and certifications.

STEM Leader Skills and Certifications.

Question 3: How important are the following skills and certifications for STEM leaders?

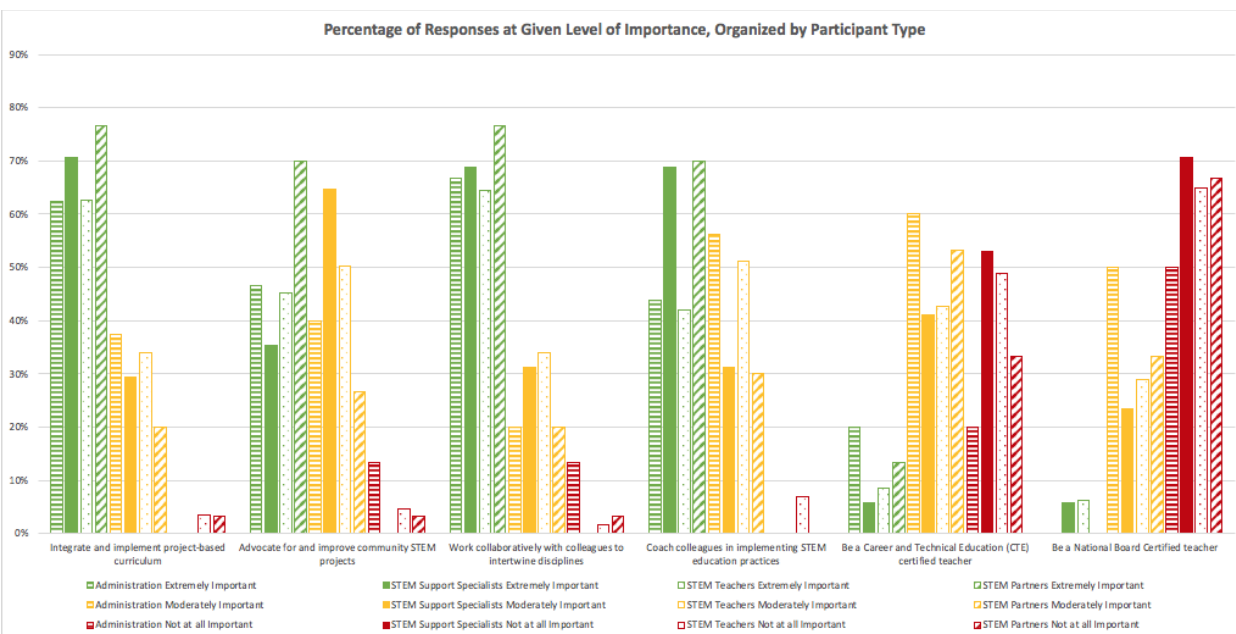

Figure 7. Summary of average rankings of each statement in Question 3 for each stakeholder subgroup of participants.

	How important are the following skills and certifications for STEM leaders?			
	Administration ***(16 responses)***	***STEM Support Specialists*** ***(17 responses)***	***STEM Teachers (177 responses)***	***STEM Partners**** ***(30 responses)***
Integrate and implement project-based curriculum	*0.81*	*0.85*	*0.80*	*0.87*
Advocate for and improve community STEM projects	*0.67*	*0.68*	*0.70*	*0.83*
Work collaboratively with colleagues to intertwine disciplines	*0.77*	*0.84*	*0.81*	*0.87*
Coach colleagues in implementing STEM education practices	*0.72*	*0.84*	*0.68*	*0.85*
Be a Career and Technical Education (CTE) certified teacher	*0.50*	*0.26*	*0.30*	*0.40*
Be a National Board Certified teacher	*0.25*	*0.18*	*0.21*	*0.17*

Table 8. Weighted averages for the different stakeholder subgroups addressing Question 3.

Discussion. Analyzing results from question 3 helps us understand the importance survey respondents place on STEM leaders acquiring particular skills and/or certifications. Pertaining to important skills for STEM leaders to have, a strong consensus emerged regarding the importance of being able to *integrate and implement a project-based curriculum* with most subgroups identifying this as the most important skill. The other highly rated skill across all groups is the ability to *work collaboratively with colleagues to intertwine disciplines*. The remaining skills of *advocating for and improving community STEM projects* and *coaching colleagues in implementing STEM education practices* were still described as important to respondents, however to a lesser degree and less consistently across subgroups. For instance, STEM partners tended to rate the importance of community STEM projects more highly than teachers and administrators. Additionally, teachers rated the importance of coaching colleagues lower than other subgroups.

Follow-up questions revealed that STEM stakeholders felt these skills are best learned through networking and collaborating with other STEM educators in a supportive environment of like-minded STEM educators. Some of the STEM stakeholders are presently participating in or learning these skills. For instance, one high school teacher described a successful experience with implementing project-based instruction in an Honors Biology course. He attributed a lot of the success of this implementation to his students presenting at Central Washington University's SOURCE (Symposium for University Research and Creative Expression) program. He noted that the experience created an opportunity for authentic assessment, in that it "really pushed me to make sure my students were doing a good job on their projects and were ready to go. It kind of pushed the students too [...] It was a platform for this stuff to be presented and shared." Despite acknowledging the importance of these skills, some teachers articulated perceived barriers in their districts. For instance, one teacher noted that "currently project-based [instruction] is mostly in CTE classes. I would like to see more intentionality with it in the Math and Science classes as well." Participants commented that learning and practicing these STEM leadership skills is tied to specific educational contexts, so districts can patiently support growing STEM leaders by having STEM coaches, pair mentoring, paid time-off to collaborate, and time to collaborate with STEM educators outside their districts.

Respondents across all subgroups found both types of certification included in the survey, Career and Technical Education (CTE) and National Board Certification (NBC), less important for a STEM leader than the particular skills that were surveyed. However, all subgroups did rate CTE certification as more important than NBC. In follow-up questions, STEM stakeholders identified several benefits of obtaining CTE certification, such as the ability to "work collaboratively with industry" as a worksite learning coordinator. Moreover, CTE certification allows one to teach specialized courses such as financial algebra, coding, or engineering classes, sometimes to the extent that teaching "anything other than your traditional math and science classes [requires] CTE. So having collaboration between the CTE and non-CTE classes could be very helpful." However, stakeholders acknowledged that not all subgroups benefit from CTE in the same manner or to the same extent. As one focus group participant pointed out, "If it's an administrator, there's a huge fiscal advantage [...] in a class you're going to get [a fixed amount of] money per student for your school. Well if that's also a CTE class, that student gets counted again and you get federal Perkin dollars for that student." On the other hand, participants mentioned it can also be a "hassle" for teachers who "just want to teach [their subject]" and "lots of extra paperwork" for administrators. Accordingly, the degree to which STEM leaders might be interested in CTE certification might depend greatly on the stance of the district they are associated with.

STEM Leader Responsibilities.

Question 4: How important are the following responsibilities for a STEM leader?

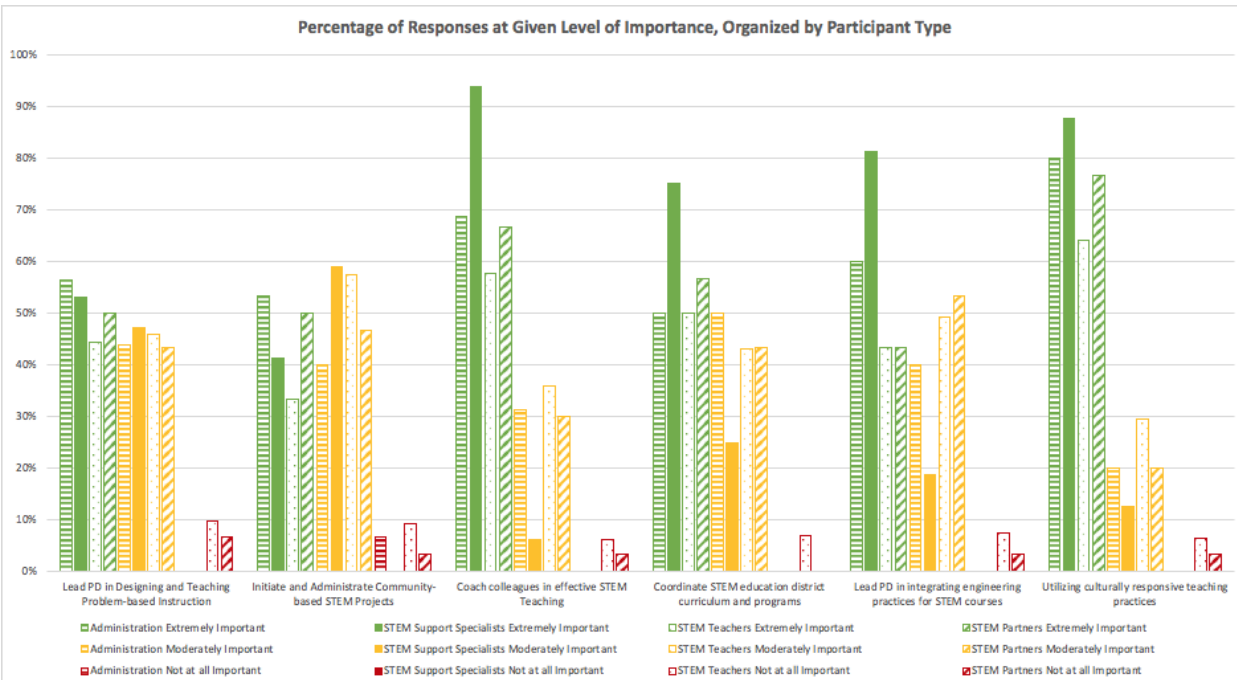

Figure 9. Summary of average rankings of each statement in Question 4 for each stakeholder subgroup of participants.

	How important are the following responsibilities for a STEM leader?			
	Administration *(16 responses)*	*STEM Support Specialists* *(17 responses)*	*STEM Teachers (175 responses)*	*STEM Partners** *(30 responses)*
Lead Professional	*0.78*	*0.76*	*0.67*	*0.72*

Development in Designing and Teaching Problem-based Instruction				
Initiate and Administrate Community-based STEM Projects	*0.73*	*0.71*	*0.62*	*0.73*
Coach colleagues in effective STEM Teaching	*0.84*	*0.97*	*0.76*	*0.82*
Coordinate STEM education district curriculum and programs	*0.75*	*0.88*	*0.72*	*0.78*
Lead professional development in integrating engineering practices for STEM courses	*0.80*	*0.91*	*0.68*	*0.70*
Utilizing culturally responsive teaching practices	*0.90*	*0.94*	*0.79*	*0.87*

Table 10. Weighted averages for different stakeholder subgroups addressing Question 4.

Discussion. Respondents across all groups reported that the six responsibilities included in the survey are important for a STEM leader. However, the responsibilities were not rated equally important by the respondents as a whole, nor was there complete consensus by subgroup with regards to the ranking of the responsibilities. While there was not clear consensus regarding the ranking of each responsibility, the overall highest ranking responsibility for both the group as a whole and for most subgroups was the responsibility of *utilizing culturally responsive teaching practices*. This finding was also substantiated in the open-ended follow-up questions, where participants collectively voiced a need for promoting diversity and equity in STEM education. For instance, one of the STEM coach/coordinator participants expressed "how important it is for students to see professionals they identify with in STEM professions. In order to draw more diversity into the STEM field, we need more STEM leaders with diverse backgrounds. Programs should promote diversity." One STEM teacher felt that "STEM education that is hands-on problem solving has a better chance of bridging gaps with equity issues and schools that struggle with cultural responsiveness, better than most any other field." Another teacher concluded, "The world is simply different, therefore the approach we take to teaching and learning must also be different. It must also be equitable."

Another aspect that was highly ranked by both the group as a whole and by most subgroups was the responsibility of *coaching colleagues in STEM teaching practices*. The remaining rank order of responsibilities based on the whole group of respondents is *coordinating STEM education district curriculum and programs, leading PD in integrating engineering practices for STEM courses, leading PD in designing and teaching problem-based Instruction,* and *initiating and administering community-based STEM projects*. As noted, there is some variation among subgroups in the ranking of responsibilities. For instance, STEM partners tended to rate community STEM projects more highly than teachers rated the responsibility and STEM specialists tended to rate coaching as a more important responsibility compared to the ratings of other subgroups. In the free-response questions, STEM teachers clarified that community-based projects can be "tricky" and "a bit ambitious" due to the variability in pacing. Another teacher noted that they might adjust the importance of leading community-based projects depending on whether they were teaching middle or high school students. This teacher elaborated, "I would place more of an emphasis on community partnerships and career and technical education in high school."

During the focus group, STEM stakeholders felt that support from their district and the greater network of STEM educators is essential to supporting STEM leaders who not only use STEM projects but are STEM champions of district and community-wide projects. One STEM teacher discussed some success that her district has had in hiring an "instructional facilitator" that "can lead the community" and "help all the other teachers be better math and science teachers." In the absence of this type of special position, one STEM teacher noted, "You need a patient administration in your district [...] I'm learning a lot of these [responsibilities] on the job [...] If they [administration] don't have patience for that process, that teacher will be pushed out before they ever acquire the skills." Another teacher hypothesized that "having a sub come cover your class so that you can lead Professional Development during school days" might be a powerful support to enable teachers to flexibly promote STEM growth in their school districts.

Question 5: Tell us about your education, certifications, and STEM teaching experience.

Question	Yes		No	
	Percent	Count	Percentage	Count
Are you currently employed by a school district?	96 %	167	4 %	7
Do you have a BA/BS in the primary discipline you are teaching or plan to teach?	85 %	149	15 %	26
Do you have a Master's Degree?	80 %	140	20 %	34
Are you CTE certified?	15 %	26	85 %	148
Are you National Board Certified?	27 %	47	73 %	127
Are you interested in designing, teaching, or participating in STEM projects?	81 %	141	19 %	33
Have you ever designed, taught, or participated in STEM projects?	68 %	119	32 %	55
Have you designed, taught, or participated in STEM projects in the districts you are presently teaching?	55 %	**95**	45 %	78

Table 11. Summary of STEM teacher participants' education, certifications, and teaching experience.

Discussion. Based on the survey results from STEM teacher respondents, the vast majority are currently employed and hold an undergraduate degree in the field in which they are primarily teaching. Additionally 80% currently also hold a master's degree. However, most teachers also report that they are still interested in additional experiences related to the designing, teaching, or participation in STEM projects, and a substantial percent of teachers do not report having had the opportunity to do this. For instance, one of the teachers explained during the open-ended questions that "As a math teacher, I do not have training or PD on STEM, STEM projects, ideas or methods to incorporate STEM into my pacing guide [...] PD on how to push these projects would be amazing!"

Putting it Together: Supporting a Washington STEM Network with STEM Leaders at the Center

In reflecting on the aforementioned results, the leadership team curated these findings into an overarching framework, pictured below. This framework represents our vision for the central role a STEM Leadership program can play in advancing STEM education. Specifically, Central Washington University's STEM Leadership program can serve two, equally important roles: (1) improving the effectiveness of STEM teachers by creating STEM leaders proficient with research-based and stakeholder-recognized pedagogical principles and practices; and (2) connecting STEM stakeholders across Washington State by organizing the program to serve as a regional STEM network hub.

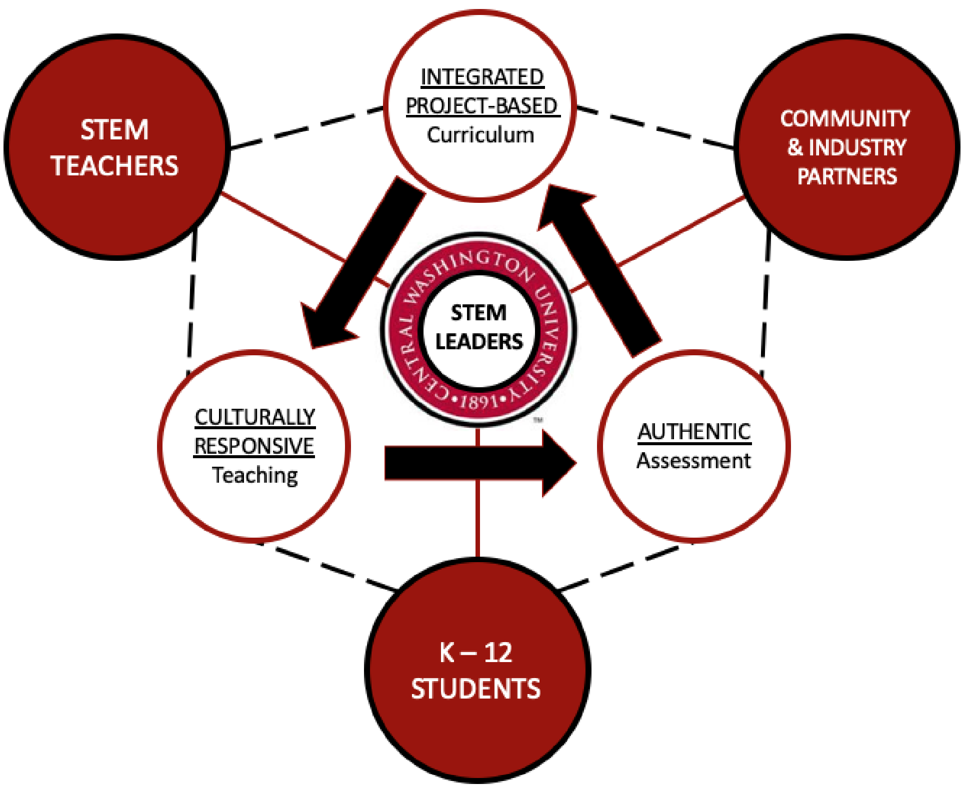

Figure 12. STEM leadership framework informing CWU program design (duplicate of Fig. 1).

Implications for Program Curriculum. The three pedagogical components of the framework (circles with red borders with black connecting arrows) model three major stages of a **plan**-revise-**teach**-**assess**-reflect-adjust teaching cycle, in which effective teachers incorporate feedback from students and experts (within the school and in industry) throughout the design process (Wiggins & McTighe, 2006). Survey and interview results elucidated key features of these components with regard to the current STEM education landscape in Washington state. Note that the following features are inherently related and are present in *all* phases of the teaching cycle, but they are especially important at certain phases.

1. Curriculum must be centered around project-based units that are integrated across disciplines. Planning project-based units involves collaboration between STEM teachers within the school, as well as community and industry partners outside of school. (Within the figure, these relationships are seen as dotted black lines connected to the *integrated, project-based curriculum* circle.) STEM teacher leaders must be proficient in working collaboratively with colleagues and other STEM stakeholders to design and implement project-based units.

2. Teaching must be culturally responsive. While culturally responsive teaching is an underlying assumption of all phases of the teaching cycle,[2] "[p]edagogical actions [toward creating classroom climates] are as important as (if not more important than) multicultural curriculum designs in implementing culturally responsive teaching" (Gay, 2002, p. 109). Relationships between teachers and students are the primary driver of effective culturally responsive teaching. (Within the figure, these relationships are seen as dotted black lines connected to the *culturally responsive teaching* circle.) Because the knowledge and practices involved in meaningfully implementing culturally responsive teaching go "beyond mere awareness of, respect for, and general recognition of the fact that ethnic groups have different values or express similar values in various ways," (p. 107) STEM teacher leaders can play a critical role in promoting sustainable, widespread use of culturally responsive teaching practices.

3. Assessment must be authentic. Authenticity is also an underlying assumption in all phases of the teaching cycle,[3] but authenticity in assessment is especially crucial for closing the feedback loop within the teaching cycle. Assessment

[2] Teachers must use their knowledge of cultural diversity to design culturally relevant curriculum (Gay, 2002) and innovative performance assessments (Gay, 2018).

[3] Authenticity to real life experience, both concrete vocational applications and essential philosophical questions of life and ethics, is one of the foundational aspects of Project-Based Learning (Larmer, Mergendoller, & Boss, 2015). Authenticity is at the heart of

must be authentic to students through the use of a variety of differentiated, performance-based, and asset-focused assessments. Assessment must also be authentic to real life experience, which community and industry partners have the ability to meaningfully assess. (Within the figure, these relationships are seen as dotted black lines connected to the *authentic assessment* circle.)

Implications for Program Organization. Just as important as the pedagogical components of the framework, the survey results emphasized the need for a centralized STEM network to advance STEM education. Different STEM stakeholders influence different components of the teaching cycle and, with intentional planning, this STEM Leadership program can serve as a network hub. The following are key organizational implications for program design coming from the data presented in this report:

1. A substantial number of surveyed STEM teachers have not had opportunities to design, teach, nor participate in STEM projects. Many of these STEM teachers already have a Master's degree and so would not be interested in enrolling full time in our STEM leadership program. However, these teachers expressed interest in these opportunities. For CWU's STEM leadership program to truly serve as a network hub, our program design must intentionally provide a space for all STEM stakeholders, not just those enrolled in the program. The program should serve as a hub for professional development opportunities for all STEM teachers, providing explicit opportunities for a variety of STEM stakeholders to interact.

2. National Board certification was not emphasized by survey participants. This impacts the leadership team's proposed explicit inclusion of National Board preparation within program curriculum. Instead, we will transform the dedicated pedagogy courses to better reflect the three pedagogical aspects of the framework (integrated, project-based curriculum; culturally responsive teaching; and authentic assessment).

3. In thinking about CWU's STEM leadership program as a hub for advancing STEM education in Washington State, it is important to maintain awareness of potential barriers to change. There are always systemic barriers that have historically impeded educational change and impact the design of learning environments, such as competing perceptions of how students learn and varied access to resources. As such, overcoming these barriers is a process fortified by long-term goals and a robust program curriculum. There are also logistical

barriers to teacher program participation such as locational and temporal limitations in availability, as well as resources and support from administration. Note that this framework does not explicitly include administration. However, administrators play a key role in providing the support and resources necessary for STEM teachers to develop and implement research-based STEM pedagogical practices and build relationships with community and industry partners to provide authentic experiences for their students. STEM teachers surveyed are keenly aware of these limitations, and careful program design is needed to address these logistical concerns to maximize the number of STEM teachers who can participate in the STEM leadership program.

The above considerations are discussed more explicitly in a separate report, *STEM Leadership Program Curriculum and Organization*.

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Elements of this paper are supported by the National Science Foundation, award # (FAIN) 1950332. Any opinions and findings expressed in this material are the authors and do not necessarily reflect the views of NSF. If you have any questions about the STEM Leadership Survey or STEM Education programs at Central Washington University feel free to contact Dr. Mark Oursland (oursland@cwu.edu), Dr. Allyson Rogan-Klyve (roganklyve@cwu.edu), Dr. Emilie Hancock (emilie.hancock@cwu.edu), or Dr. Brent Hancock (brent.hancock@cwu.edu).

Appendix A: Interview and Focus Group Questions

Interview Questions.

1. The survey results revealed that the statement, "STEM projects should be integrated into all STEM courses" was very important in advancing STEM education. Why is STEM integration important in your education role?

   (optional) In your school or district?

2. What tools and skills would you need to better integrate STEM into your curriculum?

3. Some educators commented that we need to understand the role of technology in STEM. What role do you think technology should play in the implementation of STEM principles?

4. What role could industry or community partnerships play in advancing STEM integration in your district?

   (optional) What would ideal community partnerships look like?

   (optional) What tools/skills are necessary to make and sustain these partnerships?

5. Many of the survey participants perceived a need for a systemic change in how we advance STEM education, including a shift towards project-based learning and meaningful integration between STEM disciplines. However, teachers also shared that they work within certain constraints (such as standardized curricula & assessment, etc.). Where have you seen success in balancing these two sets of needs, systemic change and constraints?

   (optional) What other constraints might you face and why would these constraints make implementation of integrated/interdisciplinary STEM difficult?

   (optional) What would it take to overcome these constraints, if at all?

   (optional) In what ways does this curriculum constraint make implementation of STEM difficult?

   (optional) What would it take to overcome this curriculum constraint, if at all?

6. If STEM leadership courses were offered in-person in a short summer session. What types of content or activities would you consider to be better suited to an in-person rather than on-line format?

Focus Group Questions.

1. All survey participants felt these skills were important for STEM leaders (in order):

    (a) Integrate and implement project-based curriculum;

    (b) Advocate for and improve community STEM projects;

    (c) Work collaboratively with colleagues to intertwine disciplines;

    (d) Coach colleagues in implementing STEM practices.

How have you learned or observed that these skills are best learned?

2. Most survey participants said CTE certification was only moderately important but a few felt it was very important. Is being CTE certified important, and why?

3. All survey participants felt these responsibilities for STEM leaders (order):

    (a) Utilizing culturally responsive teaching practices;

    (b) Coach colleagues in effective STEM Teaching;

    (c) Coordinate STEM education district curriculum and programs;

    (d) Lead PD in integrating engineering practices for STEM courses;

    (e) Lead PD in Designing and Teaching Problem-based Instruction;

    (f) Initiate and Administrate Community-based STEM Projects.

When have you seen a learning community that fostered growth of these responsibilities in teachers?

4. What type of support would STEM teachers need to learn and practice these responsibilities in their district?

5. Washington STEM supports STEM education through STEM Networks. How could Central Washington University support this work and promote greater collaboration of resources?